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The Journal
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Animal Morphology and Physiology

EDITORIAL

FOR a long time a desire to have a distinctive Indian journal to publish papers on morphology and physiology was in the minds of many of us engaged in research in these two branches of Zoological Science. This journal is the natural outcome of that desire.

There has often been a tendency to treat morphology and physiology as two water-tight compartments. In starting a combined journal of morphology and physiology, the aim is to stress the complimentary nature of these two subsciences and their importance in elucidating the organismal make-up.

The primary purpose of a scientific journal of this type is to publish original papers. Secondarily the journal will serve two purposes. It will stimulate research in the two pa[illegible] fields it encompasses, and it will also set a standard for research work in those. By presenting this journal the promoters hope that these purposes will be amply served and they request research workers to make use of its pages.

The main difficulty in a venture of this kind is the finance required to run it. The promoters have faith in the future and they solicit the co-operation of fellow Zoologists to see that the publication goes on uninterruptedly, by sending contributions and donations.

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THE MYOLOGY OF THE HEAD AND NECK OF THE COMMON INDIAN POND TURTLE, *LISSEMYS PUNCTATA GRANOSA* SCHOEPFF

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WHILE anatomical descriptions of several reptilian types are available, the literature on their muscular system is scanty indeed. It is no surprise therefore the muscular system of the chelonia, the most modified reptilian group from the evolutionary standpoint, has remained neglected. Among the host of changes undergone by the chelonian structure to attain its present status, those of the muscular system have not been in any way less remarkable. A detailed study of the musculature of an Indian chelonian was therefore considered highly desirable and a reward ample in itself. The common Indian pond turtle *Lissemys punctata granosa* was chosen as the type animal for study. Here, to begin with, the muscles of the head and neck are dealt with, as it is felt that a knowledge of their disposition will enable us not only to compare them with those of other orders, but also to explain the varied movements exhibited by the neck. The task was rendered difficult by the general lack of pertinent literature, and more so on account of the confusion that prevails in the nomenclature of the muscles. The works of Bojanus (1820), Owen (1866), Furbinger (1870), Edgeworth (1935) and Lubosch (1938) have been of great help.

Description of the Muscles

The musculature of the head and neck comprise those concerned with the movements of the mandibles, the floor of the mouth, the eyes, the nostrils, the hyoid, the cervical vertebræ and the neck as a whole.

The *adductor mandibulae* consists of three parts: (*i*) The *adductor mandibulae externus* (*temporalis*), (*ii*) The *adductor mandibulae medius* and (*iii*) The *adductor mandibulae internus*. The *oadductor mandibulae externus* (figs. 1, 2, 4) arises from the frontoparietal crest and the apex of the supra-occipital bone. Some fibres arise also from the upper border of the quadrate and of the squamosal. These fibres decussate with those of the former at the place of origin and the whole muscle runs anteriorly and turns downwards into a very thick tendinous portion to be inserted on the coronoid process of the mandible. With the development of the transverse bony bar on either side of the skull, formed by the jugal in front, the quadrate behind and the quadrato-jugal in the middle. The *adductor mandibulae externus* gets split into the temporalis muscle above and the *masseter* below the transverse bar. It is of interest to mention here that the development of an

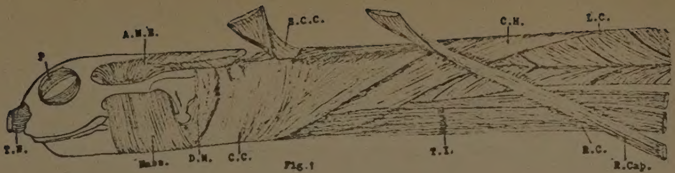


Fig.1

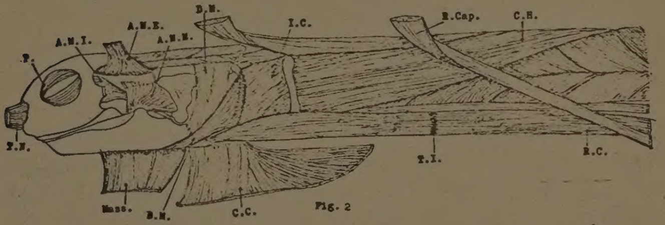


Fig. 2

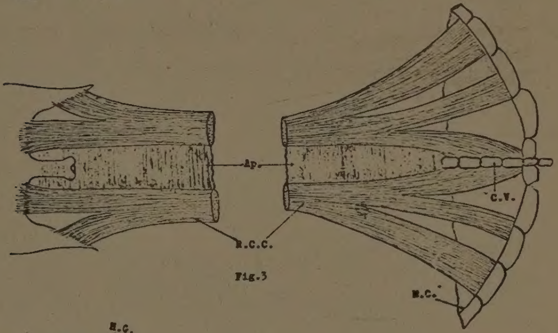


Fig.3

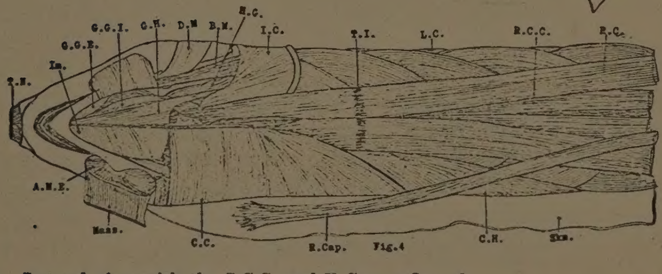


Fig.4

Fig. 1. Lateral view with the S.C.C. and R.Cap. reflected.

Fig. 2. Lateral view with A.M.E., Mass. and C.C. also reflected. A.M.E., Adductor mandibulæ externus, A.M.I., Adductor mandibulæ internus, A.M.M., Adductor mandibulæ medius, B. M., Branchio mandibularis, C. C., Constrictor colli, C. H., Constrictor hyoideus, D.M., Depressor mandibulæ, I.C., Intercornuatus, L.C., Longissimus cervicis, Mass. Masseter, P., Palpebralis, R.C., Rectus cervicis, R. Cap., Rectus capitis, R.C.C., Retrachens capitis collique, S.C.C., Spinalis cervico capitis, T.I., Tendinous intersection, T.N., Tensor nasalis.

Fig. 3. Ventral view showing the origin and insertion of R.C.C.

Fig. 4. Ventral view with the I.M. and C.C. removed on the left side and the Mass. reflected on the right.

A.M.E., Adductor mandibulæ externus, A.P., Aponeurosis, B.M., Branchio mandiblaris, C.C. Constrictor colli C.H., Constrictor hyoideus, C.V. Caudal vertebræ, D.M. Depressor mandibulæ, G.G.E., Genioglosso externus, G.G.I., Genioglosso internus, G.H., Genio-hyoideus, H.G., Hypo-glossus, I.C., Inter-cornuatus, L.C., Longissimus cervicis, Mass., Masseter, M.C., Posterior margin of carapace, R.C., Rectus cerviecis, R.C.C., Retrachens capitis colloqiue, R.Cap., Rectus capitis, Skn., Skin reflected, T.I., Tendinous intersection, T.N., Tensor nasalis.

analogous transverse bar, the zygomatic arch of the mammalian skull, causes the formation of the two muscles the *temporalis* and the *masseter*. (Quiring, '50). As for the nerve supply to these muscles it is derived from the mandibular branch of the trigeminal in Lissemys as in mammals. The *masseter* (figs. 1, 2, 4), arises from the lower border and the inner surface of the jugulo-quadrate bar and proceeds downwards and backwards as a broad belly to be inserted on the lower half of the posterior border of the mandible. The *temporalis* aided by the *masseter* acts as a powerful adductor of the mandible.

The *adductor mandibulae medius* (fig. 2) arises by two heads, one of which originates from the anterior lower border of the parietal and pro-otic bones gets a wide insertion on the coronoid process and the other arising from the anterior border of the quadrate, proceeds forwards and gains a tendinous insertion on the same process. This muscle acts as an elevator of the mandible.

The *adductor mandibulae internus* (fig. 2) has its origin from the anterior inner border of the jugal, the posterior border of the maxilla and the outer border of the palatine and the pterygoid. It proceeds backwards and downwards and gains its insertion on the inner side of the articular process of the mandible by a tendinous strip. It is an adductor of the mandible.

The *depressor mandibulae* (figs. 1, 2, 4), consists of an anterior and a posterior part, both arising from the outer upper margin of squamosal. The fibres of the two bellies of muscle decussate and form a tendon which gets inserted on the lateral side of the posterior end of the angular process of the mandible. It is a depressor of the mandible.

The *inter-mandibularis* (fig. 4) extends transversely between the mandibles and has its attachment anteriorly on the lateral sides of the dentaries, and posteriorly to the inner border of the angular bones. The muscle has an apponeurotic median raphe which is attached to the hyoid. In a relaxed state the muscle is arched upward but when contracts it is horizontal and by its rythmic contractions and relaxations the floor of the buccal cavity is lowered and raised.

The *constrictor colli* (figs. 1, 2, 4) forms a superficial sheath of muscle on the lateral side of the neck extending from the posterior end of the jaws to the middle of the neck. Dorsally the muscle is continued as fascia. Few dorsal fibres in front overlapping the *depressor mandibulae* arise from the posterior upper border of the quadrate. Ventrally the anterior fibres run parallel to the fibres of the *inter-mandibularis* and together form a muscular shelf. The posterior fibres from either side meet together to form a thin median apponeurosis. This muscle is not found throughout the entire length of the neck as in some other turtles *viz.* Emys europea (Owen, 1866). All the same it aids in maintaining the compactness of the neck that is essential for the active movements of that part.

The *branchio-mandibularis* (figs. 2, 4) arises from the posterior and the lateral borders of the distal end of the anterior cornu of the hyoid. It runs anteriorly and gets inserted on the lower border of the angular and the posterior half of the dentary. The anterior cornu has a somewhat rigid attachment to the skull at the distal end. The muscle acts as a depressor and retractor of the mandible.

The *genio-hyoideus* (fig. 4) has its origin on the inner side of the mandibular symphysis, and proceeding backwards its median fibres decussate with those of the opposite side as far back as the basihyal. Thereafter the muscle parts company with its fellow of the other side to be inserted on the cerato-hyal and the anterior border of the proximal end of the anterior cornu. This muscle acts as an elevator and protractor of the hyoid.

The *genio-glossus* muscle consists of two parts the *genio-glossus externus* (fig. 4) and the *genio-glossus internus* (fig. 4). The former arises from the lower border of the anterior half of the dentary and gains its insertion along the anterior border of the basihyal. The latter also arises from the anterior part of the lower border of the dentary, runs backwards and gets inserted along with the geniohyoideus on the lateral border of the anterior cornu at its proximal end. Both these muscles act as protractors and elevators of the hyoid.

The *hypo-glossus* (fig. 4) arises partly from the ventrolateral border and partly from the ventro-medial border of the distal end of the anterior cornu. Proceeding forwards it gains its insertion on the ceratohyal. It is a retractor and depressor of the hyoid.

The rectus *capitis cervico plastralis* (figs. 1, 2, 4) arises as a thick cylindrical belly from the sternal plate of the plastron and running fowards, upwards and laterally in the neck, flattens out and gets inserted by a thin membranous aponeurosis on the skull at the squamosal in close association with the skin. This muscle acts as a retractor of the head and flexor of the neck when the muscles of both sides act together, and as a lateral rotator of head when they act singly.

The *spinalis cervico capitis* (figs. 1, 2) arises from the spines of the third, fourth, fifth and sixth cervical vertebræ and runs anteriorly as a flat belly and gains its insertion through a broad and thin aponeurosis on the posterior border of the post-orbital. The muscle acts as an elevator and lateral rotator of the head.

The *tensor nasalis* (figs. 1, 2, 4) arises from the inner surface of the anterior border of the nasals and on the inner side of the maxilla and the fibres run along the dorsal and lateral sides of the nostrils to be inserted on the skin bordering the nostrils. The muscle on contraction acts as the dilator of the external nares.

The *hypoglosso-glossus* and the *hypoglosso-hyoideus* :—Anterior to the hyoid and ventral to the tongue, there is a cartilaginous structure known as the hypoglossum which is absent in the other reptilian groups (George, '48). From its lateral margin and from the dorso-median line of its posterior one-fourth respectively, two thin muscles arise to be inserted on the base of the hyoid respectively. We have ventured to call these muscles by the above respective names. These muscles are responsible for the movements of the tongue and the hypoglossum during deglutition.

The *inter-cornuatus* (figs. 2, 4) is responsible for the intercornual movement. The muscle occurs in very thin membranous strips running obliquely between the anterior and posterior cornua.

The *rectus cervicis* (figs. 1, 2, 4) arises from the dorsal surface of the medial end of the corocoid and runs all along the entire length of the neck on the ventral side and during this course the medial fibres of the two sides decussate more or less in the middle of the muscle. A little in front of this, a tendinous intersection is formed and thereafter the muscles of the two sides part company, each one dividing into three bellies which come to lie one over the other. The ventral belly runs over the posterior cornu and gains its insertion by a thin tendon on the anterior border of the cerato-hyal. The middle one is inserted on the hyoid at the point where the ceratohyal and the basihyal meet, the dorsal belly running along with the œsophagus, merges with the wall of the œsophagus and the pharynx. The nerve supply to this muscles is derived from the hypoglossi. The *rectus cervicis* of the lower tetrapods gives rise to the omohyoid, sterno-mastoid and sterno-thyroid in the mammals. The long ventral belly of the *rectus cervicis* could be regarded as the omohyoid, the middle one as the sterno-thyroid and the dorsal one is the special muscle which is inserted on the œsophagus to facilitate the movement of the œsophagus along with the neck at the time of the retraction of the neck. It is therefore not very accurate to call the whole of the *rectus cervicis* as the *omohyoideus* as Owen has done. The rectus cervicis, in this animal, is so specially developed because of the great movements of the neck.

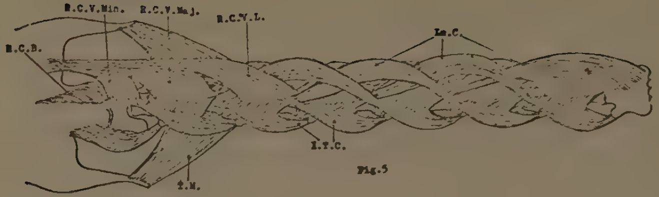
The muscles of the eye are six in number and need no particular comment except that one or more muscles acting on the nictitating membrane which are present in other Chelonia (Leuckart, 1876) Crocodilia and Aves (Edgeworth, '35) are absent in Lissemys.

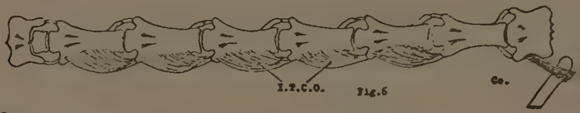
The *constrictor hyoideus* (figs. 1, 2, 4) arises in three bellies from the region of the neural spines of the 5th, 6th, and 7th cervical vertebræ. Three bellies unite to form a single muscle mass which runs on the lateral side and turns ventrally to be again divided into three parts prior to insertion. The most lateral part gains its insertion on the posterior border of the distal half of the posterior cornu, the median one is inserted on the posterior border of the proximal half of the posterior cornu, while the middle one proceeding over the posterior cornu gets inserted on anterior border of the distal end of the cerato-hyal. The muscle acts as the depressor and the elevator of the floor of the buccal cavity and the other movements of the hyoid.

The *retrachens capitis collique* (figs. 3, 4) arises by three fleshy bellies on the either side, each having separate origin. The lateral and middle ones have their origin on the line of union of the carapace with the plastron, while the median one arises from the lateral sides of the first few caudal vertebræ. All the three bellies of either side run forward and after a little distance converge and unite to form a single belly on either side. During its course it is connected with its fellow of the opposite side by a thin aponeurosis. This aponeurotic connection is narrower in the posterior part but in the neck region it widens out taking the muscles more laterally. The muscle runs forwards all through the entire length of the trunk and the neck. On approaching the skull each belly divides into two, a lateral and a medial part. The former has a fleshy insertion on the inner ventral border of the squamosal and the latter a tendinous one on the basioccipital. The retrachens capitis collique is the most powerful rectractor muscle of the head and neck. If an aribtrary division is made at the level of the epiplastron, this muscle could be considered to be of two parts an anterior cervical and the posterior trunk one, each having different sources of nerve supply. The cervical part and the capitis cervico plastralis muscle are innervated respectively by the two branches of a nerve emerging from the middle cervical ganglion of the vagus. We have therefore ventured to consider this part of the retrachens capitis collique as corresponding to the *sterno-cledomastoid* muscle which is derived from the primitive [illegible] *capitis-cervico-plastralis* the *cucularis*. The trunk part has two sources of nerve supply, anteriorly from the fifth cervical nerve and posteriorly from the lumbo-sacral plexus and the 12th dorsal. It seems very likely that owing to the skeletal modifications in the formation of the carapace and the plastron, the *sterno-cledomastoid* muscle did not acquire posteriorly the usual skeletal attachment but proceeded backwards as long linear bundle and became continuous with the posterior, trunk, part. It is also likely that this posterior trunk part was derived from the *puboischio-femoralis*, from which the psoas muscles of the mammal were derived. The posterior most region of the trunk part has a different nerve supply (derived from the 12th dorsal nerve) which is also the source of innervation of the pubo-ischio-femoralis muscle.

The retrachens capitis collique may therefore be considered as derived from the sterno-cledomastoid in the front and the pubo-ischio-femoralis muscle mass behind.

The *semispinalis* (fig. 7) muscles arise from the entire length of the region of the neural spine of each vertebra and also the inner border of the posterior zygapophysis of the same vertebra. In its course it joins with few fibres of the *logissimus* arising from the succeeding vertebra and also the tendon of the *logissimus* arising





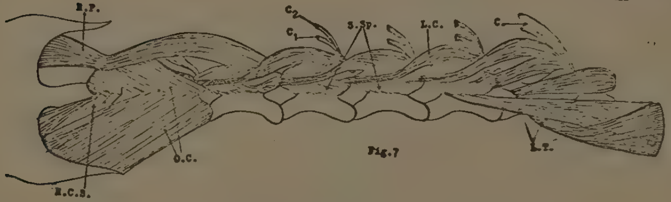


Fig. 5. Ventral view showing the hypaxial muscles. The superficial layer of muscles are removed on the right side.

Fig. 6. Ventral view showing the deepest layer of hypaxial muscles.

Fig. 7. Dorsal view showing the epaxial muscles.

C., Lateral part of the longissimus cervicis, C_1 and C_2., the divisions of the lateral part of the longissimus cervicis, Co., Coracoid, I.T.C., Inter-transversarri-colli, I.T.C.O., Inter-transversarri colli obliquei, Ln.C. Longus colli, LT., The longissimus muscles arising from carapace, O.C., Obliqus capitis, R.C.B., Rectus capitis brevis, R.C.S., Rectus capitis superficialis, R.C.V.L., Rectus capitis ventralis longus, R.C.V. Maj. Rectus capitis ventralis major, R.C.V. Min., Rectus capitis ventralis minor, R.P., Rectus profundus, S.Sp., Semispinalis.

from the second succeeding vertebra, to gain a common insertion which is partly fleshy and partly tendinous, on the posterior zygapophysis of the preceding vertebra. The *spinalis* and *semispinalis* muscles of the 7th and 8th cervical vertebræ do not exist separately as *spinalis* and *semi-spinalis*, but are represented as a single muscle mass which has its insertion on the anterior half of the region of the neural spine of the 7th cervical vertebra. The *spinalis* and the *longissimus* groups of muscles in the region of the atlas and axis are modified into occipital muscles.

The *longissimus cervicis* (figs. 5, 7) corresponding to the 7th cervical vertebra arises from the anterior zygapophysis of the 8th and in its course forwards it is divided into the medial (A), the lateral (C) and the middle (B) bellies, while the lateral belly of the one corresponding to the 6th vertebra is further divided into two C_1, C_2. The medial one (A) of the 7th is inserted on the posterior zygapohysis of the 6th. The middle one (B) runs forwards as a fleshy belly and later narrows into a tendon and joining with the fibres of the semi-spinalis and the medial belly (A) of the *longissimus* of the 6th gets inserted on the posterior zygapophysis of the

5th. The lateral belly (C) in its course forwards joins with C_1 of the 6th and is inserted on the diapophysis of the 5th while the C_2 of the 6th joins with the C_1 of the 5th to be inserted on the diapophysis of the 4th. The C_2 of the 5th, joins with C_1 of the 4th and is inserted on the diapophysis of the 3rd while the C_2 of the 4th proceeds forwards, downwards and laterally to be inserted by a tendinous strip on the lateral border of the atlas and also at the ventral side of the pro-otic. The *longissimus* of the 3rd does not possess the C_1 and C_2 bellies while the middle belly (B) which is stouter and longer than those of the succeeding vertebræ, joins with the ill-developed middle belly (B) of the 2nd to be inserted on the lateral border of the atlas by a strong tendon. The medial (A) and the lateral C_1 and C_2 bellies of the axis are absent, while the atlas does not possess any of the bellies of the *longissimus cervicis.*

The longissimus of the 1st and 2nd trunk vertebræ are well developed and arise from the carapace instead of the succeeding vertebræ. The former proceeds forwards and gains its insertion on the posterior half of the region of the neural spine of the 6th cervical vertebra. The latter arises from the dorsal, lateral and the ventral sides of the place of origin of the former so as to envelope it at the base on the three sides. In proceeding forwards, the muscle converges laterally and goes on the ventral side of the former (longissimus of the 1st trunk vertebra) to be inserted on the anterior half of the region of the neural spine of the 8th cervical vertebra.

Deep to the *spinalis-cervico-capitis* are situated the occipital muscles which comprise a medial group called the *rectus capitis* and the lateral group *obliqus capitis* (fig. 7). From the mid-dorsal line of the atlas and the axis vertebræ the *obliqus capitis* arises by two broad bellies one superficial and the other deep. The former is inserted on the inner lateral border of the squamosal and pro-otic, while the latter joins with the tendon of the *longissimus* of the 3rd vertebra. The *rectus capitis superficialis* (fig. 7) arises from the mid-dorsal line of the atlas runs obliquely forwards and gains insertion on the pro-otic and the lateral side of the ex-occipital. The *rectus profundus* (fig. 7) arising from the antero-lateral border of the atlas gains its insertion on the pro-otic and opisthotic bones.

There are three layers of hypaxial muscles on either side of the bodies of the cervical vertebræ. The ventral most layer is formed of muscles known as *longus colli* (Owen). The *longus colli* of each side in the posterior part of the neck arises from the mid-ventral line of the bodies of the 8th and 7th cervical vertebræ and running fowards gets inserted on the anterior part of the 6th and posterior part of the 5th cervical vertebræ. The next anterior belly in front, arises from the median line of the body of the 6th cervical and running over the preceding one, gets inserted on the anterior and posterior parts of the bodies of the 5th and 4th cervical vertebræ respectively. Similarly those arising from the first three vertebræ have however a different course and insertion. The one arising from the 3rd vertebra, the *rectus* *capitis ventralis longus* (fig. 5) runs, forwards to gain a tendinous insertion on the pro-otic bone, while the one arising from the atlas and axis, the *rectus cervicis ventralis minor* (fig. 5) and *major* (fig. 5) respectively join with the tendon of the *rectus capitis ventralis longus.*

The *rectus capitis* ventralis *brevis* (fig. 5) arises from the anterior border of the atlas and the distal end of the basi-occipital, and gets inserted of the basi-occipital fossa. At this stage it may however be concluded that the *rectus capitis ventralis longus. rectus cervicis ventralis major* and *minor* and *rectus capitis* ventralis *brevis* all together correspond to the longus capitis of mammals.

The second layer which is above the *longus colli,* is the *inter-transversarii-colli* (fig. 5). The part corresponding to the 7th cervical vertebra arises by two heads, one narrow and tendinous arising from the diapophysis of the 8th, while the other broad and fleshy arises from the midventral line of the 7th. The fibres of both the heads, decussate to form a single short belly which proceeding forwards gets inserted on the posterior part in the mid-ventral line of the 6th vertebra by a short thin tendon. The parts corresponding to the 6th, 5th, 4th, 3rd and 2nd vertebræ show the same plan except that the insertion of the part corresponding to the 2nd is on the mid-ventral line of its odontoid process instead of on the atlas.

The *inter-transversarii-colli-obliquei* (fig. 6) forms the third layer of the muscles. The parts corresponding to the 2nd, 3rd, 4th, 5th and 6th cervical vertebræ only are represented. The posteriormost part arises from the diapophysis of the 7th vertebra and running obliquely inwards gets inserted on the entire lateral side of the 6th vertebra. Similarly the muscles arising from the diapophysis of the 6th, 5th, 4th, 3rd and 2nd vertebræ gain their insertion on the lateral sides of the 5th, 4th, 3rd and 2nd and 1st vertebræ respectively. It must, however, be mentioned that the part corresponding to the atlas which is larger and longer has a different insertion from the others in that a few fibres are attached on the antero-lateral border of the atlas, while the rest of the belly gains attachment on the lateral border of the basi-occipital. There is a thin long muscle arising from the fascia covering the rib in the region of scapula. It runs under cover of the scapula and gains its insertion on the lateral side of the 8th vertebra. This muscle probably belongs to the *inter-transversarii-colli-obliquei* group having been shifted from the diapophysis of the 1st thoracic vertebra to its present attachment, owing to the fusion of this vertebra with the carapace.

The *trachilo-mastoideus* (fig. 5) has a broad origin from the lateral side of the axis and the diapophysis of the 3rd cervical vertebra. It runs obliquely forwards and shaping into a narrow strip gains its insertion on the medial surface of the posterior end of the squamosal. This msucle brings about the lateral rotation of the head.

Movements of the Head and Neck

Among the reptiles, the turtles and tortoises are conspicuous by the long and powerful neck which is capable of performing a great variety of movements. The principal movements of the head and neck are protraction and retraction. Retraction may be complete when the head and neck are completely within the body shell or partial when only a part of the neck is within. When these parts are in the protracted state the following additional movements are observed ; flexion, flexion and lateral rotation, extension or elevation, extension and lateral rotation and lateral flexion.

The retraction of the head and neck is effected by the simultaneous contraction of the *capitis plastralis*, the *retrachens capitis collique* and the *rectus cervicis*. In the protraction of the head and neck the retractor muscles relax and it appears as though this act of protraction is a passive one.

The other movements are possible only when the head and neck are in a partly or fully protracted state. Flexion is brought about by the contraction of the hypaxial group of muscles and also a part of the *longissimus* muscle. The hypacial group also brings about lateral flexion when only the muscles on one side contract.

Flexion is effected by the contraction of the entire group of hypaxial muscles, with the aid of the *longissimus, spinalis-cervico-capitis, constrictor hyoideus* and *rectus cervicis*. The *capitis plastralis* of one side then contracts and brings about the lateral rotation of the head and neck.

Extension of the neck and elevation of the head are brought about by the simultaneous contraction of the epaxial muscles of both the sides. This is an important movement specially when the animal has to raise its head above water for breathing.

Extension is brought about by the contraction of the *spinalis-cervico-capitis, semispinalis* and *longissimus* muscles. Lateral rotation is effected then by the *capitis plastralis, rectus cervicis* and *constrictor hyoideus* of one side. When these muscles relax medial rotation is effected.

When the *semispinalis, longissimus* and the three layers of the hypaxial set of muscles of one side contract, a powerful lateral flexion is effected thus aiding the limbs in motion. A change of direction in swimimng is also accomplished.

When a turtle is turned turtle, it quite elegantly rights itself. It shoots out its head stretching the neck to the utmost and the head turns dorso-ventrally backwards so that the dorsum of the head almost abuts against the carapace. In this position, by pressing the head on the ground, the neck is suddenly straightened by the simultaneous contraction and relaxation of hypaxial and the epaxial muscles respectively of the neck. In this process, the body with the help of the limbs of the same side is turned over to its normal position. The neck in turtles as already hinted is a strong and powerful organ. The almost interwoven arrangement of muscles, not only adds to its strength and compactness but also to the ability for performing those versatile movements.

Cervical muscles attached to the hyoid deserve a special mention because they are responsible for the movements of the floor of the buccal cavity.

When the head is retracted, the œsophagus and the trachea are also pulled back. The contraction of the dorsalmost part of the *rectus cervicis* which merges with the wall of the œsophagus renders the smooth retraction of the œsophagus and the trachea.

Summary

A somewhat complete account of the cranial and cervical musculature of *Lissemys punctata granosa* (Schoepff) is given. A great degree of specialisation not met within the other reptilian groups has been noted in this animal.

A bony transverse bar, the juguloquadrate bar, formed by the jugal in front, the quadrate behind the quadrato-jugal in the middle, divide the *adductor mandibulae externus* into an upper *temporalis* and a lower *masseter* muscle in the same manner as the zygomatic arch of the mammalian skull enables the formation of the *temporalis* and the *masseter* muscles in the mammals.

The *inter-mandibularis* is a specially organised muscle which aids in the lowering and raising of the floor of the mouth. The hypoglossum cartilage, absent in other reptilian groups has special mucsles to facilitate its movements as well as that of the tongue. These have been termed *hypoglosso-glossus* and *hypoglosso-hypoideus*. A well-developed *constrictor colli* keeps the neck compact and aids in its active movements.

The muscles of the eye are six in number, while the one or more muscles of the nictitating membrane which are present in crocodilia, other chelonia and aves are absent. The *tensor nassalis* muscle acts as the dilator of the nostrils.

The *rectus cervicis* extending from the coracoid to the hyoid, shows a transverse tendinous intersection more or less in its middle and is divided anteriorly into three bellies, two of which are represented in the mammals as the omohyoid having a tendinous intersection and the sternothyroid, while the third one to the œsophaus is specially developed so as to facilitate the retraction of the œsophagus along with the head and neck, into the body shell.

The *retrachens capitis collique*, the longest muscle in the chelonia, is a composite muscle, formed by the *sterno-cleido-mastoid* derived from the primitive rectus cervicis, anteriorly and the *puboischio-femoralis* posteriorly.

The epaxial and the hypaxial muscles of the neck shows the primitive segmental arrangement. The *longissimus* of each segment is divided into three parts which show an interwoven arrangement that is greatly responsible for the compactness, strength and the interveterbral, movements of the neck. In the posterior part of the neck at the level of the anterior thoracic vertebræ, the epaxial and the hypaxial muscles are ill-developed or absent due to the presence of the carapace which considerably reduces the intervetebral movements.

The action of the various muscles concerned in the principal movements of the head and neck, *viz.* : protraction and retraction, flexion, flexion and lateral rotation, extension or elevation, extension and lateral rotation, and lateral flexion, has been indicated.

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THE OCCURRENCE OF A STRIATED OUTER MUSCULAR SHEATH IN THE LUNGS OF *LISSEMYS PUNCTATA GRANOSA* SCHOEPFF

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THE respiratory mechanism in reptiles is more or less well understood except in the chelonians in which group unique problems are involved in asmuch as the rigid shell enclosing the viscera prevents contraction and relaxation of the body wall. Some ascribe throat movements as responsible for pumping air into the lungs as it takes place in a frog. Another suggestion made was that the movements of limb-girdles and neck have a part to play in bringing about inspiration and expiration. The latest paper of McCutcheon (1943) refutes the two suggestions mentioned above. This is what he has concluded. " Expiration is the result of contraction of the paired muscular membranes inclosing the viscera, the *diaphragmaticus* anteriorly and the *transverse abdominis* posteriorly ; inspiration is the result of the contraction of the paired muscular membranes inclosing the flank cavities, the *seratus magnus* anteriorly, and the *oblique abdominis* posteriorly. The latter inspiratory pair also provide the main non-rigid portions of the body wall to allow volume changes and constitute the primary breathing structures ; the former are supplementary. In contrast to mammals, the glottis is normally closed except when the movements of inspiration and expiration are in progress. The throat movements cannot pump air into the lungs and are not significantly involved in breathing."

While examining the anatomical features involved in the respiration of the pond turtle (*Lissemys punctata granosa*), it was found that (in addition to the muscles mentioned by McCutcheon) a muscular membrane covering the lungs occurs (Inner Muscle, fig. 1) . It was surmised that this enveloping muscle case must have a significant role in respiration in this species. Structurally it was found to be composed of striated muscle fibres. The fibres of this muscle arise from a small elliptical tract on the dorsum from the 2nd and 5th thoracic ribs. The exact limits of their origin are indicated in the fig. 1. After leaving their place of origin they converge ventrally not only enveloping, but also fusing with the lung, leaving only its bronchus exposed.

Another striated muscle (Outer Muscle, fig. I) occurring outside the one mentioned above, covers the lungs as well as most of the visceral organs for about 2/3 of the body cavity in its anterior region. This muscle arises from a border tract on the dorsum beginning from the 1st thoracic rib and ending with the 7th. Its exact position of origin is also shown in the fig. 1. It should be mentioned that

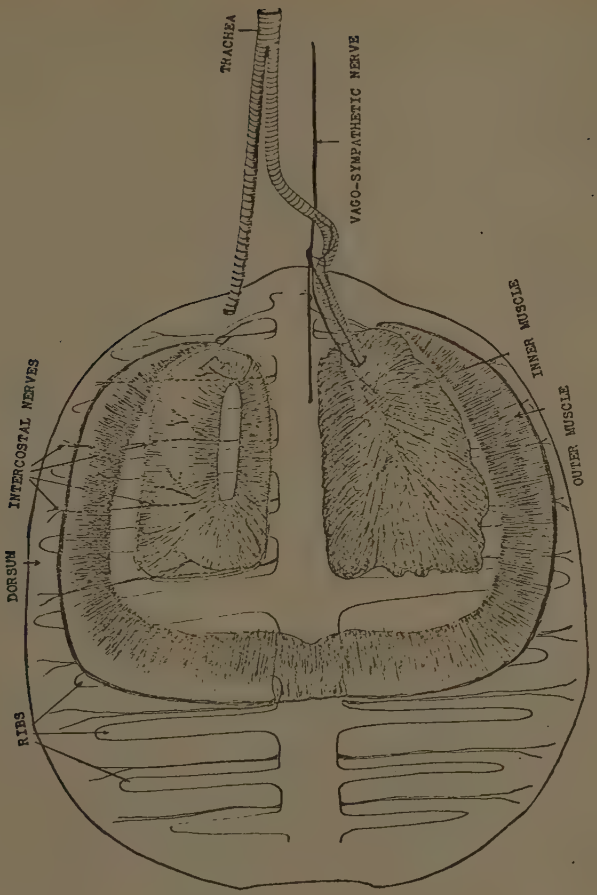

Fig. 1. A diagramatic view of the muscles covering the lungs in *Lissemys punctata granosa*.

On the left the right lung is removed along with most of the inner muscle covering to show its origin from the dorsum, disposition and nerve supply. On the right the left lung is kept intact showing its inner muscle covering. Most of the outer muscle covering is removed, but that part intimately associated with the dorsum at its origin is retained.

though this muscle is in its origin composed entirely of fibres, as it converges towards the ventral side, the fibres thin out till a more or less membranous structure results.

The following experiment was conducted to find out the working of both these muscles. The turtle was pithed first and then the thoracic plastron was removed carefully. The nerves going to the inner muscle covering the lungs were noted and one of them was then stimulated by an induced electric current. By make and brake arrangement the stimuli were given and in response the muscle contracted. But when the current was stopped by braking it, the muscle relaxed. As the electric stimuli were given to the inner muscle, the outer muscle-covering which surrounds most of the viscera also responded. This suggests that during expiration both these muscle coverings contract and compress the lung tissue which pushes the pulmonary air out. When these muscles relax, the pressure in the lung falls and air enters the lung, and thus inspiration is caused.

On examination of the structure of the lung, it is found that the alveoli are comparatively large and the inter-alveolar spaces filled with smooth muscle fibres which are grouped in large bundles (fig. 2). This enormous amount of smooth muscle in the lung of this animal is a remarkable feature, since in other amniotes though smooth muscle, is present, its extent is limited. It is surmised that the lung is pressed to contraction as a result of the combined action of the outer striated muscle covering, the inner enveloping muscle as well as the smooth muscle of the lung tissue. This is an unusual arrangement not met with elsewhere.

The outer enveloping muscle which covers most of the visceral organs including the lungs, can be homologised to the *diaphragmaticus* plus the *transverse abdom-*

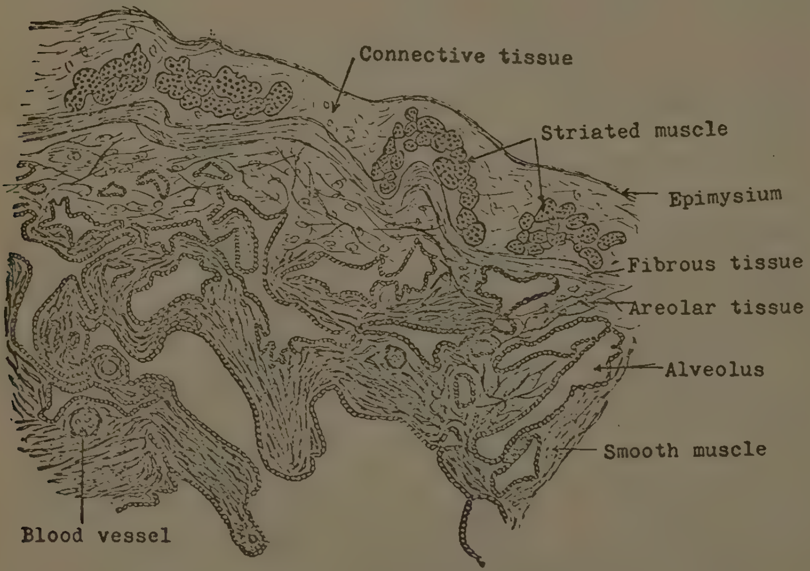

FIG. 2. A *camera lucida* sketch of a portion of a transverse section of the lung of *Lissemys punctata granosa.*

inis though the boundries of these two muscles are not demarcated as in *Emys europea* (Owen, 1866) or as in *Malaclemys centrata* (McCutcheon, 1943). The homology of the inner muscle covering, however remains doubtful. From its position it is reasonable to assume that it represents the intercostal muscles. Here in this case instead of having the original pattern of insertion and origin, the fibres seem to have lost their insertion and migrated inwards to closely envelop the lungs This supposed homology receives confirmation from the fact that the corresponding nerves to the intercostal muscles in other reptiles, birds and mammals, innervate this muscle.

Summary

A muscle covering composed of striated muscles enveloping the lungs occurs in *Lissemys punctata granosa*. Another muscle covering occurs outside the one mentioned above. This envelopes in addition to the lungs most of the visceral organs. When one of the nerve supplying to the inner muscle covering was stimulated, the outer muscle covering also contracted. It is shown from this behaviour of the two muscle coverings that together they play a part in expiration. It is surmised that when they relax inspiration is caused.

The lung tissue in this animal consist of a large amount of smooth muscle. It is believed that it also helps expiration and inspiration.

The outer muscle covering can be homologised to the *diaphragmaticus* plus the *transverse abdominis*, while the inner one to the *intercostals*. The latter homology receives confirmation for the fact that the corresponding nerves to the intercostals in others innervate this muscle also.

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THE BLOOD-VASCULAR SYSTEM OF *PANULIRUS POLYPHAGUS* (HERBST)

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As in other decapod crustaceans the blood-vascular system of *Panulirus polyphagus* consists of a heart, arteries and sinuses. Since the arteries do not divide into capillaries in these animals, but empty into blood spaces, an extensive system of sinuses occurs in the various organs and around the viscera. Two portions of the sinus system in the thorax, however, are cut off from the main blood space. One of these is the dorsal pericardial sinus, the floor of which is formed by a tough, but thin pericardial septum. The other is the sternal sinus situated below the horizontal shelf of the endophragma. The pericardial septum extends anteriorly to the cervical groove where it merges with the connective tissue lining of the hypodermis. (Figs. 1, 2A). Anteriorly the pericardial septum is pierced by the ophthalmic, antennary and hepatic arteries which proceed to their respective organs. Posteriorly the septum joins the intersegmental membrane between the thorax and abdomen. On the ventral side the pericardial septum is pierced by the sternal artery which proceeds downwards to the sternal sinus to join the ventral aorta (subneural artery). The dorsal aorta which originates from the posterior end of the heart is fused with the pericardial septum till it makes its exit into the abdomen. The sides of the pericardial septum are joined to the epimeral wall where it joins the endophragma. On each side the pericardial septum is pierced by six branchio-pericardial openings through which blood from the gills reaches the pericardial sinus.

The sternal sinus is in communication with the perivisceral blood space in the thorax by a median opening of the endophragma through which also passes the sternal artery. The afferent branchial arteries draw their blood supply from the sternal sinus.

The Heart

The heart of *Panulirus polyphagus* is an elongated roughly hexagonal muscular organ with a rather broader anterior end. It is situated in the pericardial sinus which on account of the anterior, posterior and lateral attachments of the pericardial septum becomes a closed chamber except for the six pairs of branchio-pericardial openings. The heart is kept in position in the pericardial sinus by three sets of delicate connective tissue strands which arise from the connective tissue coat of the heart and radiate from it in a symmetrical manner upwards, downwards and towards the sides. It is so suspended as to facilitate its rhythmic contraction and relaxation. When these strands are severed from the heart, it shrinks and assumes an ovoid shape.

Dorsal suspension of the heart (Figs. 1, 2B) :—Four pairs of dorsal strands attach the heart to the connective tissue of the hypodermis lining the carapace. They comprise an anterior dorsal pair, a posterior dorsal pair, and two pairs of dorso-median strands. The anterior dorsal strands arising from the anterior dorsal aspect of the heart diverge from one another and proceed upwards and forwards finally reaching the anterior part of the carapace. Of the two pairs of median strands on the dorsal side, the front pair is directed antero-laterally, and the hind pair postero-laterally. The posterior dorsal suspenders diverge from one another, and radiate backwards and upwards towards the carapace and are finally attached there.

Ventral suspension of the heart (Figs, 1, 2B):—The four pairs of ventral strands are symmetrical with the dorsal ones, but run in the opposite direction and are attached to the pericardial septum below.

Lateral suspension of the heart (Figs. 1, 2B)—Of the two pairs of strands which form the lateral suspending elements consist of an anterior pair directed antero-laterally and a lateral pair directed laterally. The anterior strands diverge from one another and finally fuse with the upwardly arching wall of the pericardial septum. The lateral strands arise broadly from the sides of the heart but narrow down later and proceed in opposite directions to get attached to the hypodermis of the epimeral wall. The absence of a postero-lateral pair of strands is compensated by the fusion of the dorsal aorta with the pericardial septum till the former pierces the latter and proceeds to the abdomen.

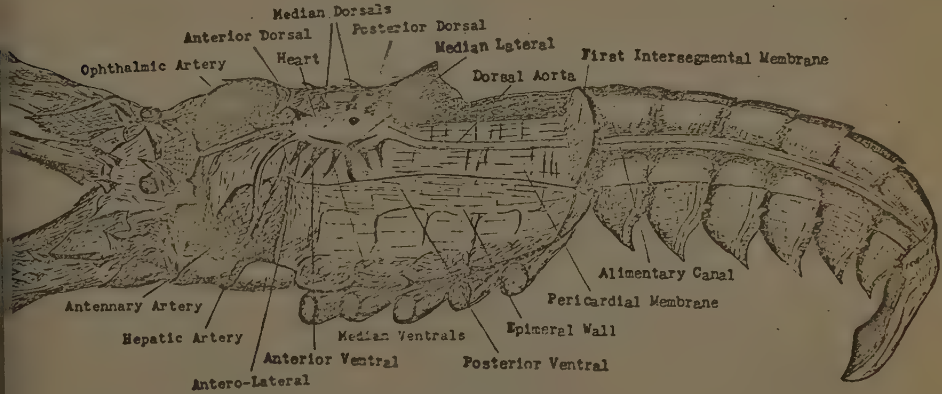

Fig. 1—The Suspension of the Heart in Panulirus (lateral view).

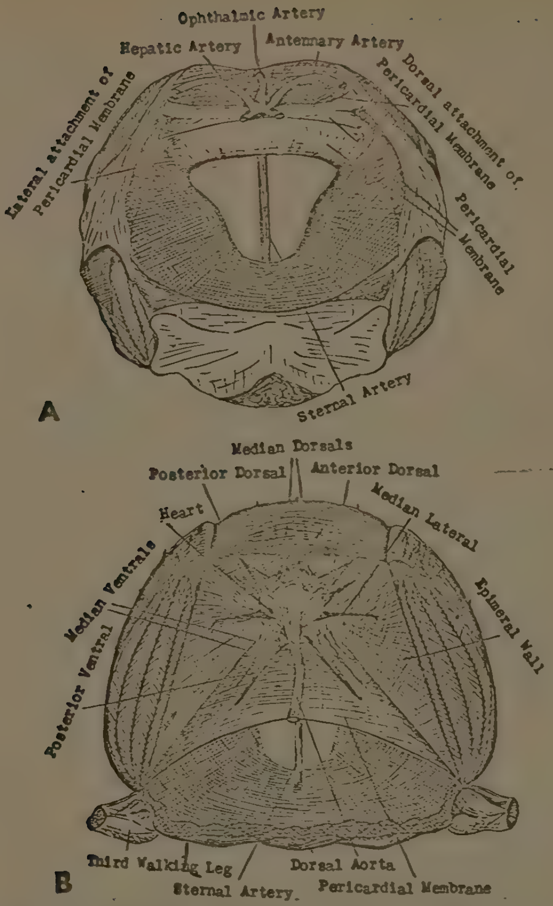

Fig. 2A—Limits of the Pericardial Membrane in Panulirus (anterior view).
B—The suspension of the Heart in Panulirus (posterior view).

The Openings of the heart :—The wall of the heart is pierced by three pairs of ostia. The front pair is situated dorsally at about a third of the length of the heart from the anterior end. The second pair is placed dorso-laterally at about two-thirds of the heart length from the front end. The third pair of ostia is located on the lower surface of the heart slightly behind the second pair. The anterior pair is a little more closely placed than the posterior one, whereas the ventral pair is closer still. An ostium consists of an oval aperture in the connective tissue coat of the heart with a slit between the muscle blocks. As the heart contracts the ostia close and when it relaxes they open and permit blood to fill its cavity.

The Musculature of the heart (Fig. 3) :—When the heart is laid open along its middorsal line, its muscular structure is made clear. It is made up of a number of muscle blocks that take a more or less diagonal course and interlace with each other, so much so that the whole picture shows the appearance of a basket work. The central cavity of the heart is very narrow indeed, while the interstices between the muscle blocks also contribute to some extent towards the cavity of the heart.

The Arteries

One median and two pairs of lateral arteries arise from the anterior end of the heart. The median one is the ophthalmic artery which is a thin vessel. The lateral ones are the antennary and hepatic arteries. From the posterior end of the heart issues the main dorsal aorta which on entering the abdomen runs along the middle line above the intestine. It gives off a pair of branches to each abdominal segment (Fig. 4). The sternal artery which arises from posterior ventral end of the heart runs vertically downwards and on reaching the sternal sinus joins the ventral aorta (subneural artery, Fig. 5).

The Ophthalmic artery :—It runs forwards along the mid-dorsal line over the pyloric and cardiac divisions of the stomach. It then pierces the pericardial

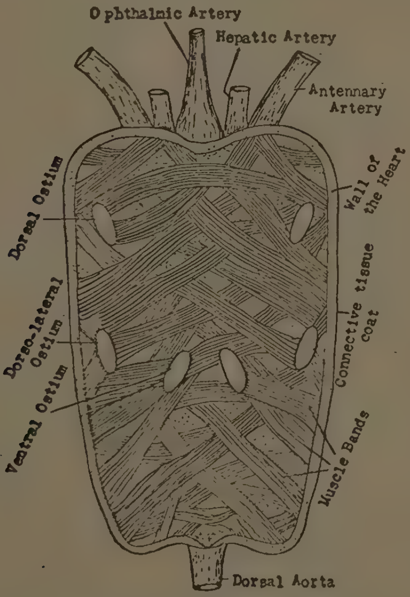

Fig. 8. The heart cut open along the middorsal line to show its musculature.

membrane at the cervical groove and runs forward. At the base of the eyestalks it dividies into two branches, one reaching each eye.

The Antennary arteries :—They lie on either side of the ophthalmic artery. Each antennary artery starts from the anterior outer margin of the heart and after piercing the pericardial septum proceeds forwards and outwards. After passing

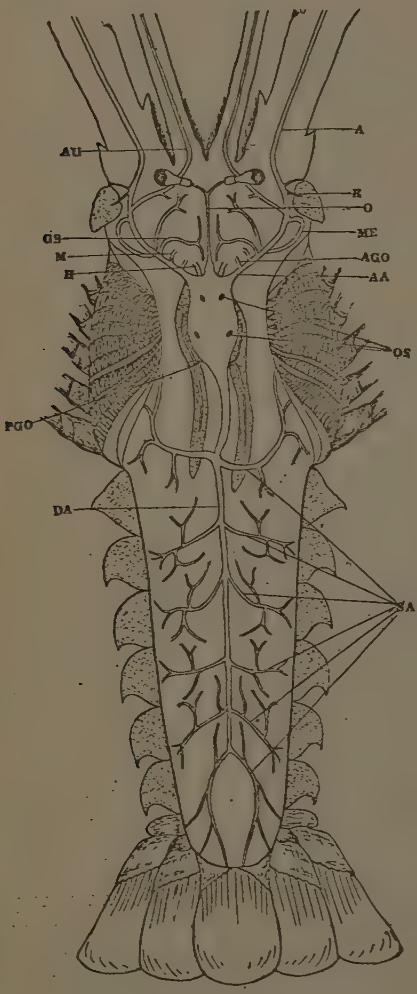

Fig. 4—Blood vessels of Panulirus (dorsal view).

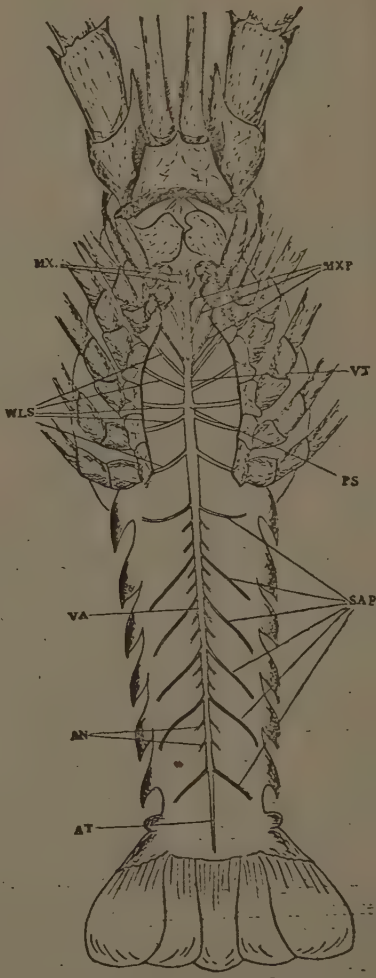

Fig. 5—Blood vessels of Panulirus (ventral view).

outside the adductor muscles of the mandibles, turns forwards and proceeds to the antenna. It gives off during its course the following arteries :—

(1) Just at its origin and soon after leaving the heart it gives off a small gonadial artery. This proceeds forwards and enters the middle portion of the reproductive organ just where it is connected to its fellow on the other side by a narrow bridge.

(2) A little beyond, it gives off a mandibular artery which proceeds obliquely forwards and inwards to supply the adductor muscle of its side.

(3) Again it gives off a little farther a gastric artery. The gastric artery passes inwards towards the stomach and divides into two. The anterior of these supplies the posterior gastric muscles. The posterior ramifies the lateral wall of the pyloric stomach.

(4) At the place where the antennary artery turns forwards, it gives off a branch which loops inwards and descends into a hollow of the apophysis of the mandible of its side. It then divides into three branches. One of these branches supplies the adductor of the mandible while the other two supply the œsophagus.

(5) Thereafter the antennary artery gives off from its inner aspect the antennulary artery. This branch originates very close to the posterior part of the recess in which the antennary gland is lodged. It proceeds obliquely inwards and forwards and close to the roots of the eyestalks gives off a small branch which supplies the muscles of the antenna. Then it proceeds forwards to the antennule.

(6) A short thick artery is given off a little ahead from the outer aspect of the antennary artery. This is the artery to the antennary gland. It runs downwards into the recess where the antennary gland is lodged and enters the latter at its anterior face.

(7) Immediately after, originates a delicate vessel which proceeds to the ventral side between the mandible and the antenna of its side and supplies the muscles of the latter.

(8) There are several small arteries arising from the antennary artery between the mandibular and gastric arteries, but these are variable in number and they supply the adductor muscles of the mandible.

The Hepatic Arteries :—These originate immediately ventral to the antennary arteries. Each of them proceeds forwards and then pierces the pericardial septum proceeds downwards and supplies first the hepatic duct of its side. Another branch from each supplies the midgut. Farther on both of them divide into two and the resulting branches subsequently divide forming numerous branches which supply the liver lobes.

The Dorsal Abdominal Artery :—The main dorsal artery after it leaves the heart is fused with the pericardial septum in the thorax. At the hind end of the thorax it pierces the pericardial septum and enters the abdomen giving off a pair of branches to each of the abdominal segments on its dorsal aspect.

(1) The first pair of abdominal artieries originates from the main dorsal artery between the thorax and abdomen. Each of them proceeds obliquely outwards and forwards and gives off first a branch which supplies the intertergal region between the thorax and abdomen. The main trunk then divides into two, one of which proceeds forwards and supplies the first flexor of its side, while the other proceeding laterally supplies the extensor muscle in the thorax as well as in the first abdominal segment.

(2) The second pair of abdominal arteries, not very symmetrical in appearance as they originate at different lengths of the main artery, proceeds backwards and outwards and each gives out first a branch which supplies the intertergal muscles between the first and second abdominal segments and the second main flexor of its side. Farther each gives of a branch which supplies the third main flexor of its side as well as the extensor of the second abdominal segment of its side. After this the main trunk proceeds forwards and supplies the intertergal muscles between the second and third abdominal segments.

(3) The third pair of abdominal arteries proceeds backwards and outwards and first gives off from each an anterior branch. This supplies the third main flexor of its side as well as the intertergal muscles of its side between the third and fourth abdominal segments. Later a branch is given off from the posterior aspect which supplies the fourth main flexor of its side. The main trunk then proceeds outwards and divides into an anterior and a posterior branch. The former supplies the intertergal muscles between the third and fourth abdominal segments, while the latter supplies the muscles of the fourth abdominal segment.

(4) The fourth pair of abdominal arteries proceeds outwards and each gives a small branch from its anterior aspect. This supplies the fourth main flexors of its side. A small branch arising from the posterior aspect and the main trunk supply the interrtergal muscles between the fourth and fifth abdominal segments.

(5) The fifth pair of abdominal arteries proceeds outwards and slightly obliquely backwards. Soon after each of them gives out a fine branch which proceeds forwards and supplies the intestine in that region. Farther a branch is given out from each and this supplies the fifth main flexors and the intertergal muscles between the fourth and fifth abdominal segments as well as the extensors of the fifth abdominal segment. The main trunk and a posterior branch finally supply the intertergal muscles between segments five and six.

(6) The sixth pair of abdominal arteries is the posterior bifurcations of the main dorsal artery. Each of these branches proceeds backwards and gives off an artery to the intestine and two arteries to the muscles of the uropods of one side. Finally each proceeds backwards and downwards to supply the muscles of the telson.

The Sternal Artery :—This is an unpaired artery arising from the posterior ventral side of the heart. Immediately after leaving the heart it pierces the pericardial septum and gives off an artery to the gonad of either the left or the right side. It then proceeds down and after passing through in the endophragma and the two nerve cords of either side joins the subneural artery.

The gonadial artery from the heart :—This is a tiny artery given off from the heart just at the junction of the sternal artery and the main dorsal artery.

The Subneural artery :—That part of the subneural artery which lies anterior to the junction between it and the sternal artery is termed the ventral thoracic artery, while the posterior part is known as the ventral abdominal artery though the latter covers also some part of the thorax. The ventral thoracic artery as it proceeds anteriorly gives off serially from its outer aspects a pair of branches to each of the three pairs of walking legs as well as to the third pair of maxillipeds. After this it divides into symmetrical branches. Each of these trunks gives off arteries from behind forwards to the second maxilliped, first maxilliped, as well as the first and second maxillæ of its side.

The so-called ventral abdominal artery gives off first paired arteries to the fourth and fifth pair of walking legs. In the abdomen it runs close to the nerve cords and gives off a pair of symmetrical branches in each segment. It also supplies the nerve cord with numerous branches throughout. Posteriorly it supplies the last part of the intestine and the telson.

The Circulation of Blood

The main force required for the propulsion of blood to the various organs through the arteries is supplied by the heart. It contracts about 32 times a minute. As it contracts, the ostia close and blood is forced into the arteries. There is a pair of folds situated at the root of each artery, which obviously prevent a backward flow of blood as the heart relaxes. Such valvular folds are present at the roots of minor arteries as well. As the heart relaxes the ostia open and blood is sucked into it.

As the heart sucks blood and forces it through the arteries, the pressure in the pericardial sinus is reduced. This fall in pressure is compensated by a flow of blood into the pericardial sinus from the branchio-cardiac channels which are in communication with the efferent branchial vessels of the gills. This inflow of blood into the pericardial sinus is ultimately drawn from the gills which means that oxygenated blood is pushed to balance the pressure in the pericardial sinus. The off-take from the efferent branchials is met by a corresponding in-take into them from the afferent branchials. Since the sternal sinus is in communication with the afferent branchials, the deficiency in them is compensated by flow from it, and as pressure gets reduced in that large reservoir blood is drawn into it from the smaller feeding sinuses of the various organs. These sinuses derive their blood from the finer arteries in the organs. Thus the circulation takes place. As demonstrated by Thomas Huxley in the crayfish, the flow of blood from the sternal sinus through the gills and the branchio-pericardial sinus into the pericardial sinus, by injecting fine carmine powder in normal saline into the sternal sinus. The carmine particles can be traced through the gills and the branchio-pericardial passages into the pericardial sinus.

The Blood

Within the body cavity the blood appears colourless and it is easily mobile. When drawn into a glass tube it appears pinkish blue. With refracted light, it looks bluish.

It contains a large number of hæmocytes. Some of these are amœboid cells and their movements are visible under the microscope. Their cytoplasm is granular, but nucleus large and round with a light amber colour in reflected light. Besides these there are larger hæmocytes which are oval or fusiform in shape. They show no movement. Each of these has a large nucleus situated near the broad end. The nucleus appears amber-coloured in reflected light. There seems to be an increase in their number at the time of moulting. In addition to these there are also small globular bodies without nucleus. They may be fragments of cells. Jellying of blood occurs readily and the hæmocytes are included in the jelly.

A large number of hæmocytes are usually met within the meshes of the antennary gland. It is quite possible that one of the functions of the glandular part of this organ is to give rise to the hæmocytes.

Reference to Lettering

A, antennary artery; *AA*, antennary trunk; *AGO*, anterior gonadial artery; *AN*, arteries to the nerves; *AT*, artery to the telson; *AU*, antennulary artery; *DA*, dorsal aorta; *GS*, gastric artery; *H*, hepatic artery; *M*, mandibular artery; *ME*, mandibulo-œsophageal artery; *MXP*, arteries to the maxillipeds *MX*, arteries to the maxillæ; *O*, ophthalmic artery; *OS*, ostia of the heart; *PGO*, posterior gonadial artery: *PS*, place where the sternal artery joins the sub-neural; *R*, renal artery; *SA*, segmental abdominal artries; *SAP*, segmental arteries to the pleopods; *VA*, ventral abdominal artery; *VT*, ventral thoracic artery; *WLS*, arteries to the walking legs.

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A COMPARISON OF THE MUSCLES IN THE FOREARM OF A FLAPPING AND A SOARING BIRD

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THE *pectoralis major* and the *pectoralis minor* form the primary muscles concerned in moving the wing as a whole. These are extrinsic wing muscles. The elegance in the execution of the flight, the graceful glide through the air and the ease with which slight wing adjustments are made, are traceable to the intrinsic muscles of the wing. As a result of adaptive radiation the mode of flight is varied in the different groups of birds. This radiation has been effected partly through the modification of the extrinsic and partly through that of the intrinsic muscles. The anatomical as well as the biochemical variations of the extrinsic muscles, the *pectoralis major* and the *pectoralis minor,* in some common Indian birds have already been referred to in my previous papers (Nair, 1951, 1952). In addition to these major changes, the other appendicular muscles, both extrinsic and intrinsic, have been modified to join in tune with the extrinsic depressors and elevators.

This paper deals with the musculature of the forearm in the representative type, each of the flapping and soaring birds, *viz.* the Parakeet (*Psittacula krameri*) and the Kite (*Milvus migrans*) respectively.

The *extensor metacarpi radialis* (EMR. fig. 1, Plate 1 ; fig. 1, Plate 2).—In the parakeet the muscle arises from the dorsal side of the distal region of the humerus by a short tendon. The muscle runs anterior to the radius, and from the distal end of the belly a cylindrical tendon is given off, which is inserted on the first metacarpal. The length of the muscle is 5 cm. while that of the belly is 3·5 cm. In the kite the muscle consists of two longitudinal divisions which are placed in such a way that one is more to the front and lies partly dorsal to the other. This divided formation begins with the splitting of the tendon at the origin. From each belly is given off a long tendon which is ultimately inserted on the first metacarpal. The length of the muscle is 14·5 cm. The belly of the first portion measures 5 cm., while that of the posterior one 3·5 cm. The inner margins of the two distal tendons are joined by connective tissue to form an apparently single tendon.

Action of the muscle : Since the tendon of the muscle passes over the distal end of the radius, and since the proximal ends of the radius and the ulna are movably articulated with the humerus, the pull exerted by the muscle when it contracts draws the first metacarpal forwards, and along with it the other metacarpals too ; and simultaneously the forearm is extended.

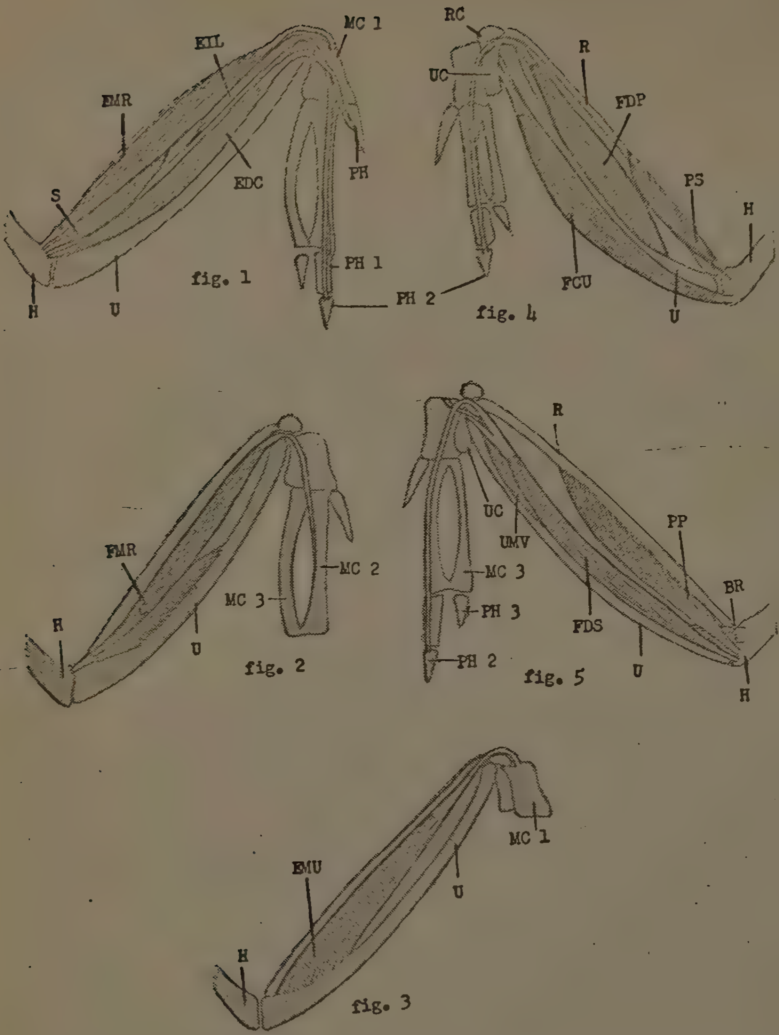

Plate 1 : The origin, course and insertion of the muscles of the forearm in the parakeet.

Plate 1, figs. 1, 2 and 3. Dorsal view of the forearm of the parakeet showing the different muscles ; figs. 4 and 5. Ventral view of the forearm of the parakeet showing the different muscles. (For reference to lettering see page 29).

The *extensor metacarpi ulnaris* (EMU. fig. 3, Plate 1 ; fig. 1, Plate 2).—In the parakeet the muscle arises from the inner surface of the proximal quarter of the ulna. The origin is fleshy. It runs towards the radial side of the forearm. Near the distal quarter of the radius the belly of the muscle gives off a tendon which is inserted on the first metacarpal dorsal to the insertion of the *extensor metacarpi radialis.* The length of the muscle is 5 cm. while that of the belly is 3·5 cm. In the kite the muscle arises from two places. One portion arises fleshy from the inner surface of the first quarter of the radius and the other, also fleshy, from that of the ulna. Both these lobes fuse near the middle of the radius, and from the common belly so formed a tendon is given off, which is inserted on the first metacarpal. The length of the muscle is 13·7 cm. while its belly measures 7·5 cm.

Action of the muscle : The action of the muscle is complementary to that of the *extensor metacarpi radialis* since when it contracts the digits are extended.

The *extensor digitorum communis* (EDC. fig. 1, Plate 1 ; fig. 1, Plate 2).—The muscle arises from the outer condyle of the humerus by a short tendon. In the parakeet the belly of this muscle extends almost up to the distal quarter of the ulna, while in the kite it extends only a little over the proximal third of the ulna. The distal tendon in both the cases passes over the distal end of the ulna and runs along the dorsal side of the second metacarpal. It gives off a branch to the phalanx of the thumb, and thereafter runs towards the tip of the wing and finally is inserted on the proximal end of the first phalanx of the second digit. The length of the muscle in the parakeet is 7 cm. while that of the belly is 3 cm. In the kite the muscle is 20 cm. in length, whereas the belly measures only 5·6 cm.

Action of the muscle : When this muscle contracts the wing is extended, the thumb is flexed towards the second digit, and apparently it is meant to prevent air from leaking through during the down-stroke of the wing.

The *extensor indicus longus* (EIL. fig. 1, Plate 1 ; fig. 3, Plate 2).—It arises fleshy from the inner border of the distal half of the radius, and the long tendon which issues immediately passes over the distal end of the ulna and runs towards the proximal end of the second phalanx of the second digit, where it gains its insertion. The length of the muscle in the parakeet is 6·5 cm., while its belly is 2·6 cm. In the kite the muscle is 15·5 cm. long, while its belly is only 5·3 cm. in length.

Action of the muscle : When the muscle contracts the second digit is extended.

The *pronator sublimis* (PS. fig. 4, Plate 1 ; fig. 2, Plate 2).—This muscle arises from the inner condyle of the humerus by a short tendon. It is inserted along the ventral side of the radius. In the parakeet the insertion is fleshy and it covers half the length of the radius. The length of the muscle is 2·3 cm. In the kite the distal portion of the muscle gives off a flat tendon which is inserted along the ventral side of the proximal quarter of the radius. The length of the muscle in this case is 4·2 cm.

Action of the muscle : The contraction of this muscle brings about the downward rotation of the anterior border of the forearm.

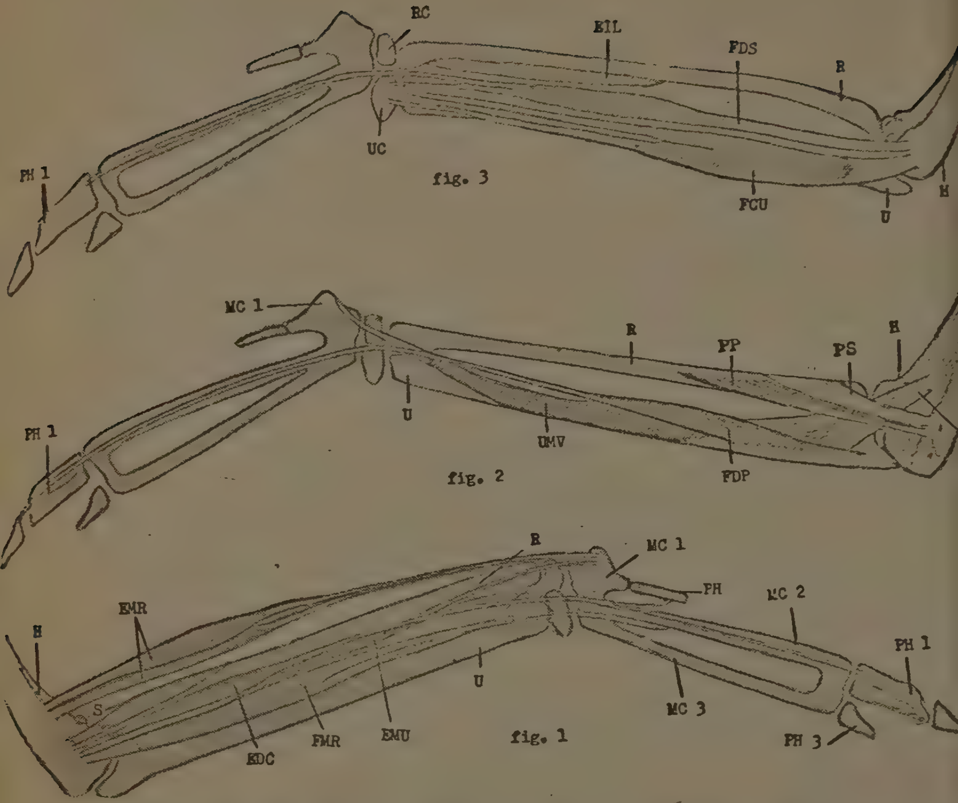

Plate 2. The origin, course and insertion of the muscles of the forearm in the kite.

Plate 2, fig. 1. Dorsal view of the forearm of the kite showing the different muscles; figs. 2 and 3. Ventral view of the forearm of the kite showing the different muscles.

BR. brachialis inferior; *EMR.* extensor metacarpi radialis; *EMU.* extensor metacarpi ulnaris; *EDC.* extensor digitorum communis; *EIL.* extensor indicus longus; *FCU.* flexor carpi ulnaris; *FMR.* flexor metacarpi radialis; *H.* humerus; *MC* 1. first metacarpal; *MC* 2. second metacarpal; *MC* 3. third metacarpal; *PH.* phalanx of the first digit; *PH* 1. first phalanx of the second digit; *PH* 2. second phalanx of the second digit; *PH.*3. phalanx of the third digit; *PS.* pronator sublimis; *R.* radius; *RC.* radiale; *S.* supinator; *U.* ulna; *UC.* ulnare; *UMV.* ulni metacarpalis ventralis.

The *pronator profundus* (PP. fig. 5, Plate 1; fig. 2, Plate 2).—It arises by a short tendon from the inner condyle of the humerus posterior to the origin of the *pronator sublimis* and lies internal to it. After running along the inner surface of the radius it is inserted fleshy along three-fourth the length of that bone in the parakeet. The length of the muscle is 2·7 cm. In the kite the distal portion of this muscle gives off a flat tendon which is inserted along the ventral side of the second quarter of the radius. The length of the muscle in this case is 5·5 cm.

Action of the muscle : Since this muscle has a greater range, its contraction augments the downwards rotation of the radius.

The *ulni metacarpalis ventralis* (UMV. fig. 5, Plate 1 ; fig. 2, Plate 2).—This muscle arises fleshy from the ventral and the inner surface of the distal region of the ulna. It tapers towards the radius where the fibres converge to a tendon which is inserted on the first metacarpal. In the parakeet this muscle measures 2 cm. and in the kite 8·5 cm.

Action of the muscle : When the muscle contracts the preaxial border of the digital portion of the wing is rotated downwards.

The *supinator* (S. fig. 1, Plate 1 ; fig. 1, Plate 2).—It arises from the dorsal side of the outer condyle of the humerus by a short tendon. It is insetred fleshy along the dorsal side of the radius. The length of the muscle is 1·6 cm. in the parakeet and 3·5 cm. in the kite.

Action of the muscle : The muscle by its contraction brings about an upward rotation of the preaxial border of the radius.

The *brachialis inferior* (BR. fig. 5, Plate 1 ; fig. 2, Plate 2).—This is a small, flat pale muscle which arises fleshy from the preaxial surface of the distal region of the humerus. The fibres are inserted fleshy along the inner surface of the proximal quarter of the ulna.

Action of the muscle : It brings about the flexion of the forearm.

The *flexor carpi ulnaris* (FCU. fig. 4, Plate 1 ; fig. 3, Plate 2). It is a single muscle in the parakeet, while it is divided into two in the kite. In the former it arises from the inner condyle of the humerus by a short tendon. From the belly a short tendon is given off, which is inserted on the ulnare. The length of the muscle is 4·5 cm., while its belly is 3·2 cm. in length. In the kite the originating tendon is broad and gives rise to two bellies. Each belly gives off a tendon near the middle of the ulna. These tendons are separately inserted on the ulnare. The length of the muscle is 12·5 cm. The belly of the upper half is 8·5 cm. in length, while that of the lower half is 7 cm. in length.

Action of the muscle : When the muscle contracts the digital portion of the wing is flexed towards the forearm.

The *flexor metacarpi radialis* (FMR. fig. 2, Plate 1 ; fig. 1, Plate 2).—This muscle arises from the dorsal side of the outer condyle of the humerus by a short tendon. Immediately after its origin it divides into two lobes, one dorsal and the other ventral. In the parakeet the ventral lobe is inserted fleshy along the inner surface of the first three quarters of the ulna. On the other hand the dorsal lobe tapers into a tendon near the distal end of the ulna, which passes over the end of that bone and is inserted on the inner surafce of the second metacarpal. The length of the muscle is 5·5 cm. and that of the belly is 4 cm. In the kite the ventral lobe is inserted fleshy along the inner surface of the first half of the ulna. The dorsal lobe gives off a long tendon near the middle of the ulna, which is inserted as in the case of the parakeet. The length of the muscle in this case is 14·5 cm. and that of the belly is 7·5 cm.

Action of the muscle : When this muscle contracts it brings about a slight flexion, of the forearm as well as the digits.

The *flexor digitorum sublimis* (FDS. fig. 5, Plate 1 ; fig. 3, Plate 2).—In the parakeet this muscle arises from the ventral side of the inner condyle of the humerus by a short tendon. The muscle after running along the ulna gives off a tendon near the distal end of that bone. This tendon gives off a slip to the ulnare and then it runs towards the second phalanx of the second digit, where it is inserted. The length of the muscle is 7·8 cm., while that of the belly is 3 cm. In the kite the originating tendon is flat and 3·5 cm. long. The belly of the muscle is 6 cm. in length. The tendon which arises distally is also a flat one which is divided at the wrist into two portions, a flat portion which is inserted on the ulnare, and a long cylindrical one which is inserted on the second phalanx of the second digit. The length of the muscle is 21 cm.

Action of the muscle : This muscle is concerned with the flexion of the digits of the wing. When it contracts a partial flexion of the digits of the wing is noticed.

The *flexor digitorum profundus* (FDP. fig. 4 Plate 1 ; fig. 2, Plate 2).—In the parakeet this muscle arises fleshy along the inner surface of the ulna between its first and third quarter. The belly which is 2·7 cm. long gives off a long tendon near the distal end of the ulna. The length of the muscle is 7 cm. It then passes over the ulna and then along the ventral side of the second digit, and finally is inserted on the proximal end of the second phalanx of the second digit. In the kite the length of the muscle is 17·5 cm., while the belly is only 5·5 cm. in length.

Action of the muscle : The action of this muscle is similar to that of the *flexor digitorum sublimis*, since when it contracts it brings about a slight flexion of the digits of the wing.

Discussion

A comparative study of the myology of the forearm of the two birds mentioned above, reveals certain interesting morphological peculiarities which may be attributed to the different modes of flight exhibited by these two birds. The muscles which show considerable variations are the *extensor metacarpi radialis*, the *extensor metacarpi ulnaris*, the *flexor carpi ulnaris*, the *pronator sublimis* and the *pronator profundus*. The *extensor metacarpi radialis* is a single bellied muscle in the parakeet, while in the kite it shows two divisions. The *extensor metacarpi ulnaris* arises entirely from the ulna in the parakeet, whereas in the kite it has a double origin, one from the ulna and the other from the radius. The *flexor carpi ulnaris* is a single muscle in the parakeet, while it is divided into two portions in the kite. In a soaring bird most of the intrinisic wing muscles have to be kept in a state of contraction for a long time than in a flapping one. When kept tense these muscles get fatigued soon and have to be relaxed. If such muscles are divided into two and each division is capable of acting independently, there will be no occasion for either of them to get over fatigued. It is suggested therefore that these muscles are split in the soaring bird to facilitate soaring by preventing fatigue.

In the parakeet the area of insertion of the *pronator profundus* covers three-fourth the length of the radius and that of the *pronator sublimis* covers half of the length of the radius, while in the kite the area covers the second quarter and the proximal quarter of the radius respectively. Since the area of insertion of these muscles, in relation to the length of the radius, is more in the parakeet the contraction of these muscles will bring about a greater degree of pronation of the forearm. Flapping flight involves a greater deflection of the component parts of the wing.

The ratio between the length of the belly and that of the muscle bears some relation to the mode of flight of the birds under discussion. Below is given a table showing this ratio for each of the four extensor and four flexor muscles mentioned in this paper.

Name of the muscle	$\frac{\text{Length of the belly}}{\text{Length of the muscle}}$	
	Parakeet	Kite
Extensor metacarpi radialis ...	0·7	0·29
Extensor metacarpi ulnaris ...	0·7	0·55
Extensor digitorum communis ...	0·43	0·28
Extensor indicus longus	0·4	0·34
Flexor carpi ulnaris	0·76	0·64
Flexor metacarpi radialis	0·73	0·52
Flexor digitorum sublimis	0·38	0·28
Flexor digitorum profundus ...	0·36	0·32

From the table it is seen that for one cm. length of the muscle the length of the belly is always more in the parakeet than in the kite. This is what is to be expected in a flapping bird like the parakeet when we recall the fact that flapping flight involves a greater range of extension and flexion, and for greater play of the different parts of the wing a longer belly is necessary. This increase in the belly length seems therefore to be correlated with the mode of flight of the bird. Since the contractile portion of a muscle, taken in relation to its length, is more in the parakeet than in the kite, a greater deflection of the point of insertion occurs in the former. It is evident from the table that all the muscles in the kite show a diminution in the belly length. This is in no way a handicap for a bird which flies on outstretched wings making use of the rising air currents. Movements of the wing are largely confined to its digital portions, and they are of the nature of slight flexions and extensions ; for such actions a long belly is not very economical.

Summary and Conclusions

1. The various muscles of the forearm in the parakeet and the kite are briefly described. Their actions are pointed out as far as possible.

2. The *extensor metacarpi radialis* is a single muscle in the parakeet, while it is a double bellied muscle in the kite.

3. The *extensor metacarpi ulnaris*, in the parakeet, has a single origin, entirely from the ulna. In the kite it has a double origin, one from the ulna and the other from the radius.

4. The *flexor carpi ulnaris* is a single bellied muscle in the parakeet, while it is a double bellied one in the kite.

5. It is suggested that the splitting of the muscles in the kite is a means to facilitate soaring by preventing over-fatigue.

6. The *pronator sublimis* and the *pronator profundus* have wider range in the parakeet. Hence the degree of rotation of the radius in that bird is more than that in the kite.

7. The length of the belly calculated per unit length of the muscle in many of the forearm muscles is more in the parakeet than in the kite. Since flapping flight involves a greater range of extension and flexion a longer belly is necessary. This increase in the belly length is therefore in correlation with the mode of flight of the parakeet.

Acknowledgment

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STUDIES IN THE PHYSIOLOGY OF DIGESTION IN *PILA VIRENS* (LAMARCK)

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THE Gastropods show a great diversity in their diet, and we may therefore expect the mechanism of feeding and digestion to be much more varied in this group than in the Bivalvia. Our knowledge of digestion in Gastropoda is confined, however, only to a few forms and is mostly due to the investigations of Yonge (1923-38), Graham (1932-38 and 39), Krijgsman (1936), Rosen (1925 and 1934) Manson Beck (1934), Howells (1942), Fretter (1937), Millot (1895) and Morton (1951). The more important forms that have been investigated so far are *Helix*, *Patella*, *Murex*, *Pterocera*, *Vermetus*, *Turritella*, *Aplysia* and a few Opisthobranch molluscs like *Philine*, *Haminea*, *Scaphandra* and *Jorunna*.

The present investigation deals with the feeding and physiology of digestion in *Pila virens*, the common apple snail of South India.

Material and Methods

Specimens of *Pila virens* were collected from the freshwater ponds in the campus of the Annamalai University, and were kept for observation in sufficient numbers in the aquaria in the laboratory.

For studying the feeding currents, the living stomach was isolated and opened in physiological saline solution, and the course of the currents followed with the aid of carmine particles and carborundum powder of different grades, the observations being made under the stereo-binocular microscope.

Experimental feeding of the animal was carried out in the laboratory. The animals were previously starved and subsequently fed on the experimental diets. Filter paper, Indian ink, boiled rice, iron saccharate, olive-oil, stained with Sudan III, citrus fruits (oranges), egg albumin and milk were used in these experiments.

For histological work, Bouin's fluid, Zenker's fluid, Mercuro-formol and 'Flemming without acetic' were employed. Staining was carried out either with Delafield's Hæmatoxylin and eosin, or Heidenhain's Iron alum Hæmatoxylin. Mucicarmine was employed for the demonstration of mucus cells. Some material was fixed in Champy's fluid and also in Nassanov's mixture for cytological study. For animals fed on iron saccharate and iron lactate, fixation was done in a mixture of Bouin's fluid and ammonium sulphide, and the iron detected later in the sections by the Prussian Blue reaction, as described by Yonge, (1926).

For the study of the enzymes, extracts of salivary glands and of the digestive gland were prepared by grinding the tissues with quartz sand and extracting the enzyme with distilled water. Toluene was added to the extract in every case to serve as an antiseptic. The test tubes containing the extracts and the substrate were kept in the incubator, but ordinarily no special regulation of temperature was required, as the laboratory temperature averaged above 32°C during the time of experiments. Rigorous controls with the boiled extracts were always employed and the experiments were always carried out with extracts prepared from adult animals. Experiments were also conducted to determine the optimum conditions for the physiological activity of the digestive enzymes. For testing the action of the enzymes on carbohydrates, the extract of the gland was prepared in the manner already mentioned, and to separate portions of the extract the different carbohydrates were added, controls of boiled extract being always kept. Glucose being the final product of digestion of all carbohydrates, the presence of glucose was tested with Fehling's reagent and Benedict's reagent after allowing the action of enzyme on the carbohydrates for a day. To test whether there is an intermediate stage of carbohydrate digestion with maltose as the product, osazone was prepared six hours after the commencement of the action of the enzymes on the carbohydrates. The presence of lipase was tested by its action on phenol-red milk and olive oil. The ' copper soap test ' was also performed as a confirmative test for the presence of lipase.

The Alimentary Canal

Prashad (1925) has given a complete account of the alimentary canal of *Pila globosa.* The account does not, however, include the description of food-sorting mechanism in the stomach. The main features in the structure of the alimentary canal relevant for the present investigation are as follows :—(*i*) The mouth is situated at the anterior end of a partly retractile snout and leads into a buccal cavity. A pair of jaws are situated at the anterior end of the buccal cavity. (2) the buccal mass contains as in other Gastropods the odontophore and a well developed radula with stout teeth bearing prominent sharp cusps. The radula has the typical Tænioglossate formula. The central cusp in the rachidian tooth and in the lateral teeth is sharp and large. On the sides of the posterior end of the buccal mass are a pair of fair-sized salivary glands and lying beneath each of them is an œsophageal pouch. The two œsophageal pouches open into the buccal mass. The buccal mass is followed by the œsophagus which opens into the stomach which is roughly U-shaped and divisible into a cardiac and a pyloric portion. The pyloric portion gives rise to a short cæcum which does not contain a crystalline style. The intestine is very long and coiled. The digestive gland consists of two main lobes and the ducts from these two main lobes unite and have a common opening into the stomach. The stomach has a thick muscular investment composed of longitudinal and circular muscles. The lining of the alimentary canal is generally ciliated being composed of what Prashad described as rodlet cells. Gland cells of the eosinophil type are present throughout.

The internal structure of the stomach is of importance in connection with the food-currents which will be described later on.

The stomach, as already stated, consists of an anterior, or cardiac chamber and a posterior, or pyloric chamber. Forming the boundary between the two portions

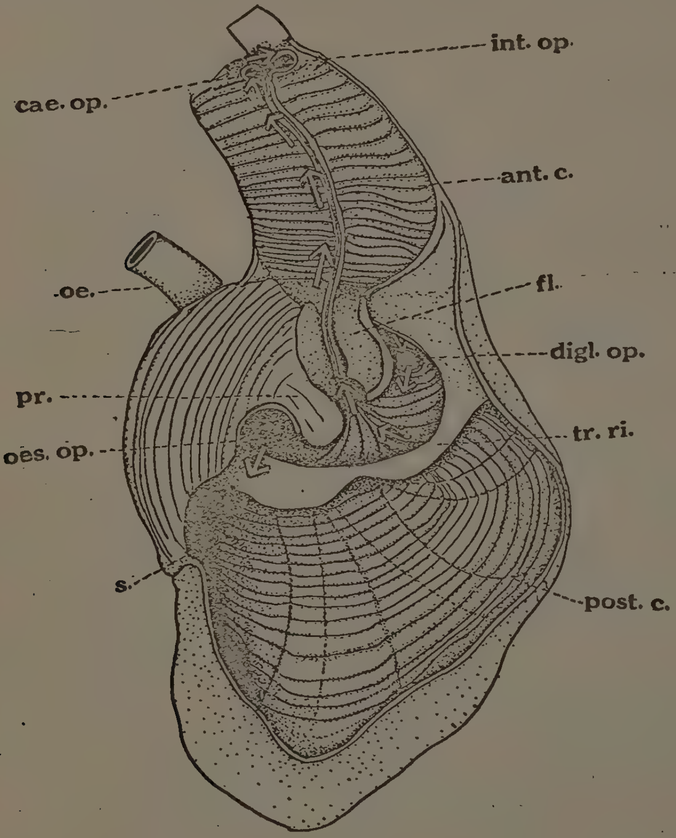


FIG. 1

Food currents in the Stomach of *Pila virens*—The living stomach has been cut open along the right margin and the dorsal wall spread out to the left. X *ca* 10.

ant. c. anterior chamber ; *cœ.* cæcum ; *cœ. op.* cæcal opening ; *con. tis.* connective tissue ; *digl.* digestive diverticula ; *digl. op.* opening of the digestive diverticula ; *exc. sph.* excretory mass in excretory spherioles ; *fe.* earlier stages of iron absorption in the digestive cells ; *fe.s.* iron in the excretory spherioles ; *fl. flap.*; *gr.* groove on the left margin of the anterior chamber ; *int.op.* intestinal opening ; *œ.* œsophagus ; *œ. op.* œsophageal opening ; *post. c.* posterior chamber ; *pr.* prolongation of the cut wall of the stomach ; *rid.* ridge ; *s.* *sac* like portion of the posterior chamber ; *sd.* semi-lunar aperture ; *v.s.* vertical septum.

is a ridge which runs transversely and then obliquely upwards and forwards into the pyloric chamber. This can be seen from Text fig. 1., which represents the inner view of the stomach when exposed by cutting it open along the left margin and reflecting the dorsal wall.

The digestive diverticula have a common opening into the stomach. This opening is situated in a semilunar, depressed area of the cardiac chamber of the stomach. This area is separated from the region of the œsophageal opening by a vertical septum. (Fig. 2 B and C). A stout flap arising from the ventral wall is situated adjacent to the opening of the digestive diverticula. This prevents the passage of food from the œsophageal opening to the region of the opening of digestive diverticula.

The inner lining of the stomach is not even, but shows a number of grooves. In the crescentic depressed area, a number of ciliated grooves converge into a groove on the margin of the stomach, immediately to the left of the flap as seen in Fig. 1. These grooves start mostly from the periphery of the semilunar depressed area, but a few start from the neighbhourhood of the opening of the digestive diverticula. The anterior chamber is continued forward (cephalad) as a narrow and more or less tubular prolongation. The groove to the left of the flap is continued along the right margin to the cæcum. The dorsal and ventral walls of this prolongation of the anterior chamber contain transverse folds. Between the cæcal opening and the intestinal opening there is a slit-like communication (Text-fig. 1).

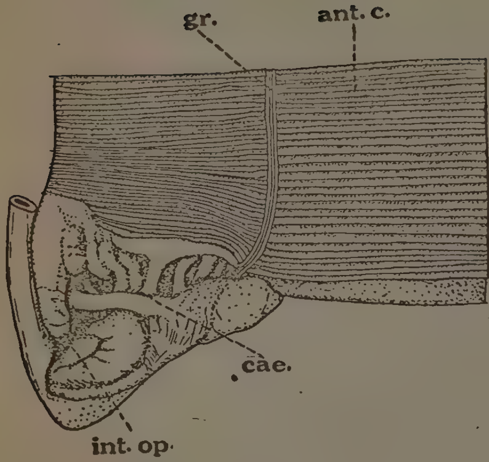
In the pyloric chamber the left portion is deeper and communicates anteriorly over the transverse ridge with the region of the œsophageal opening in the cardiac chamber. Simiarly on the right side, the pyloric chamber, which, however, is shallow, connects over the transverse ridge with the semilunar depressed area.

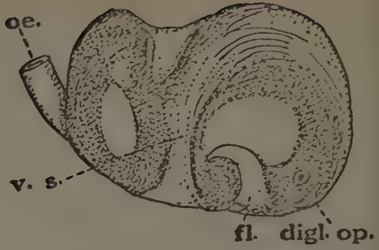
Feeding and Food Currents

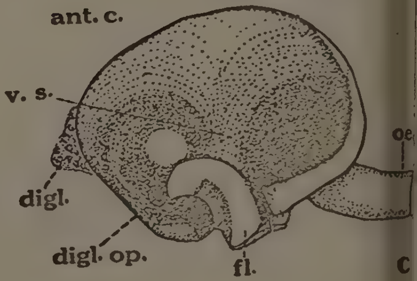
The food and feeding habits of *Pila* have been described by Ramanan (1900) and Prashad (1925). The food consisting of succulent aquatic vegetation is cut up by jaws, as described by Prashad (1925). The radula does not seem to have any rasping functions, serving only for pulling the food back into the œsophagus. It has also to be mentioned that the animal does not feed continually, but only at varying intervals.

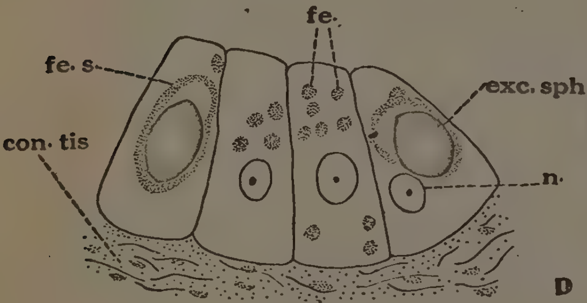
From the buccal cavity the food mixed with the salivary secretion is conducted into œsophagus. The passage of the food in the œsophagus is probably brought about by persistalsis.

The stomach is of particular interest with regard to the food currents in it. For the study of these currents carmine particles were used. The food coming









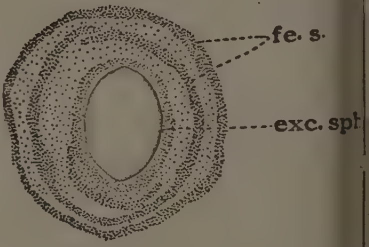


Fig. 2. A

Dissection of the anterior chamber in the region of the cæcal opening to show the internal structure of the cæcum. X *ca* 20.

Fig. 2. B

Transverse section of the stomach (gross) in the region of the œsophagus viewed from behind (posterior end). X *ca* 15.

Fig. 2. C

Same as Fig. 2B but viewed from the anterior side. X *ca* 15.

Fig. 2. D

Cells of the digestive diverticula of *Pila virens* fed on iron saccharate showing absorption of iron. X *ca* 620.

Fig. 2. E

Excretory spheriole. X *ca* 800.

(For reference to lettering see page 37) through the œsophagus is directed by what we have called the transverse ridge into the pyloric chamber and evidently gets mixed there with the secretion of the digestive diverticula which might flow into the posterior chamber. The disposition of the transverse ridge and the position of the openings of the digestive gland are sufficient to effect this process. Text-fig. 2B and C are sketches of sections of the stomach of *Pila* at the level of the œsophageal opening viewed from the posterior and anterior sides respectively. The figures show how the food from the œsophagus and also the secretion of the digestive gland might flow into the posterior chamber.

When carmine particles are dropped in the crescentic depression of the anterior chamber, they travel along the radiating grooves of this area and finally join the longitudinal groove leading to cæcum. The particles do not pass into the pyloric chamber, being prevented by the transverse ridge. Any particles dropped at the opening of digestive gland itself also travel into the radiating grooves and finally join the stream in the longtitudinal groove leading to the cæcum. Particles falling a little anterior to the crescentic depression and also round about the flap, also move into the radiating grooves and join the longitudinal groove.

The current in the longitudinal groove leads to the cæcum and from there it emerges to pass into the intestinal opening. As it passes into the intestinal opening, the consistency of the current is changed. The particles are entangled in a thread-like stream of mucus.

No ciliary currents were observed in the posterior chamber. The movements and the passage outwards of its contents are evidently brought about by mucsular action. We have already pointed out that the wall of the stomach contains circular and longitudinal muscles.

The course of the events of digestion in the stomach may be summarized as follows :—The food arriving through the œsophagus passes over the transverse ridge and largely accumulates in the posterior or pyloric chamber. The digestive juice flows into the right part of the posterior chamber where extra-cellular digestion takes place. The flap adjacent to the opening of the digestive diverticula appears to direct the digestive juices into the posterior chamber and also prevent solid, or heavy particles entering into the opening, for the flap can be shut over it. But excretory spherioles from the digestive gland were seen coming out of the opening and joining the current to the cæcum. The undigested matter is all directed into the longitudinal groove proceeding to the cæcum. When the stomach of an animal fed on filter paper was opened, it was found that fine shreds or fibres of filter paper were in the left part of the posterior chamber. The remaining part of the stomach, as far as the cæcum, contained material of a softer consistency.

Evidently, the material after mixing with the digestive juice passes into the anterior chamber, where the digested material is absorbed and the rest directed forward. While the food is in the anterior chamber absorption takes place. The further absortion of the digested material and the consolidation of the waste material will be described later on.

Feeding Experiments

The natural food of the animal consists of aquatic vegetation like *Vallisnaria*, *Hydrilla* etc., but under experimental conditions *Pila* can feed on a variety of substances like filter paper, boiled rice, sweet oranges etc. The animals were also made to take in Indian ink, saccharate of iron, boiled egg, gelatin, Congo fibrin etc. Of all the substances filter paper was consumed most readily and in surprisingly large quantities. For feeding with filter paper, a peice of filter paper measuring about 6″ by 5″ was placed each in a jar containing one or two specimens of *Pila*. In the course of a day all the filter paper in each jar was usually eaten by the animal. After two days' feeding on filter paper, the fæcal pellets were found to consist entirely of the remnants of the digestion of filter paper *i.e.*, pulp of filter paper.

The animals were also fed on boiled rice but this was not taken in such large quantities as filter paper.

For finding out the results of the digestion in the above experiments, the contents of the stomach after feeding were tested with Benedict's reagent and Fehling's solution. In the case of filter-paper feeding and also boiled rice, the stomach contents showed the presence of glucose. The stomachs of animals fed on other experimental diets were also examined in the live condition.

Iron Saccharate :—For feeding the animal with saccharate of iron, pieces of filter paper soaked in a solution of the substance, and then dried were employed. Fixation and staining were carried out in the manner already described. After feeding the animal for a day or two, iron saccharate, as detected by the Prussian blue reaction, was found in abundance in the cells of the digestive gland (Fig. 2D). In the intra-tubular portion of the digestive gland and in the portion of the gut other than the digestive gland no trace of iron was found. In the cells of the stomach also no absorption was seen.

Prashad (1925) distinguishes two kinds of cells in the tubules of digestive gland. (1) the gland cells and (2) ferment cells. In specimens fed on saccharate of iron, the cylindrical cells which were termed the gland cells by Prashad (1925) show the presence of iron saccharate in the form of spherioles. In the earlier stages of digestion only blue granules are evident. In the second type of cells, the so-called ferment cells, greenish brown bodies, oval or spherical are normally found enclosed in large vacuoles which sometimes fill nerly the whole cell. These cells are found in the crypts or corners of the tubules and are broadly triangular. In animals fed on iron saccharate, iron can be detected by the Prussian blue test in these ferment cells in the form of a shell enclosing the greenish brown bodies. When the animals are fed for about a week, concentric layers of iron saccharate are seen in the outer part of the spheriole (Fig. 2E). From these observations it is evident that iron saccharate is absorbed by the cells of the tubules of digestive gland.

Indian Ink :—The animals were fed on pieces of filter paper soaked in Indian ink. After four or five days' feeding, the animals were fixed and sectioned. No trace of Indian ink was found in any part of the alimentary canal except in the lumen of the œsophagus, stomach and intestine from where it is rejected. There is therefore no evidence of intracellular digestion.

From the feeding experiments we also see that the waste matter collects into the longitudinal groove and passes to the cæcal opening. The particles arriving at the cæcal opening are only in the form of loose particles. In specimens fed on filter paper the entire alimentry canal is filled with the pulp of the filter paper. In the œsophagus it is in the form of loose fibres. The fibrous material also fills the pyloric chamber. In the cæcum and at the beginning of the intestine, small pellets of consolidated fibres are formed. In the intestine and rectum the material is in the form of more compact and solid pellets.

The Salivary Gland

Besides the primary function of the production of mucus for lubrication of radula and cementing the food, the salivary glands of many gastropods secrete enzymes attacking food materials. In carnivores the secretion of a protease, and in herbivores that of various enzymes which hydrolyze carbohydrates may also be present in the salivary glands. The extract of salivary glands of *Pila* shows the presence of a very powerful amylase capable of hydrolyzing starch, a weak maltase acting on maltose, but there is no indication of glycogenase, invertase, cellulase, lipase or protease.

The Oesophageal Pouch

An extract of the œsophageal pouch was tested for the presence of enzyme and it was found to possess a weak amylase but no other enzyme.

The Digestive Gland

For investigating the enzymes of the digestive gland an extract of the digestive gland was prepared. An extract of the stomach and also the enzyme content of the stomach were studied. The secretion of the digestive gland is evidently poured into the stomach, for the extract of the stomach contains enzymes secreted by the digestive gland. In animals fed on rice and filter paper, glucose could be detected by Benedict's test in the contents of the stomach a few hours after feeding. This is possible only when the digestive juices are poured into the stomach. The extracts of the stomach and digestive gland were prepared separately and tested in all cases ; their enzymatic action was found to be similar.

All the important carbohydrases and a weak lipase were present. There is no indication of a protease.

Cellulose in the form of filter paper, grass, cotton and saw-dust were all digested by the extract of the digestive gland. The action of the enzyme on maltose, glycogen, sucrose, inulin and starch were also tested and in all cases results were positive. The presence of lipase was detected by the action of phenol-red milk and olive oil, and the ' copper soap test ' confirmed the presence of a lipase.

The relation between the time of action of the enzyme and the quantity of sugar formed was determined. Estimation of glucose was done by the Bertrand's method. From the data obtained it was evident that the amount of sugar produced was not directly proportional to the time of action but the enzyme activity diminished as the concentration of glucose within the medium increased.

Summary of Digestion in *Pila*

The food torn up by the jaws is handed over into the œsophagus. The salivary secretion contains a powerful amylase and weak maltase. The œsophageal pouches contribute a weak amylase. The food passes through the oesophagus and mixed with the secretion of the digestive gland accumulates in the pyloric chamber of the stomach. Extracellular digestion takes place in the stomach, the source of enzymes being the digestive gland. Cellulase, amylase, maltase, invertase, glycogenase, inulase and lipase are found in the secretion of the digestive gland. The cellulase has a powerful action. There is no sure indication of protein digestion. Undigested matter is consolidated and moulded into fæcal pellets in the cæcum.

Optimum pH for the action of cellulase and amylase in the digestive gland extract

The extract of the digestive gland was prepared as already mentioned. It was made up to a definite volume (200 c.c.). In each case 20 c.c. of the enzyme was pipetted out and to it added 2 c.c. of 10% starch solution, or pieces of filter paper as the case may be, different volumes of acid or alkaline was added to get different *pH* and the final volume was made up to 25 c.c. in all cases. After 24 hours all these were boiled to kill the enzyme and the amount of sugar present in each case estimated by the Benedict's method. The optimum *pH* for digestive gland amylase was found to be 6 and that for cellulase was 5·75.

Discussion

The most important features of the digestive system of *Pila* are (1) a well-developed buccal mass with triturating mechanism in the form of a pair of jaws and a radula with powerful teeth and cusps. (2) the presence of conspicuous salivary glands and œsophageal pouches, the presence of the latter being, as Graham (1939) has pointed out, an index to the extra-cellular digestion in the posterior part of the alimentary canal *i.e.* stomach. (3) A stomach without a style and style-sac, but with a short cæcal chamber at the intestinal end of the stomach. (4) The division of the stomach into a large posterior pyloric region serving for the reception and storage of food materials during digestion and an anterior cardiac chamber into which the digestive diverticula open. (5) The restriction of ciliary mechanism to the anterior chamber only (6) The presence of a long coiled intestine (7) The trabecular nature of the lumen of the cæcum.

The structure of the radula may to some extent be related to the diet and mode of feeding of the animal. The œsophageal pouches as Graham (1939) has pointed out are to be found in animals which have a rhythm in their feeding, or to which meals come at irregular and unpredictable intervals. As already indicated, this also indicates the state of extra-cellular digestion. This is what we find in *Pila*.

The formation of the fæcal pellets is effected in the cæcum, whose structure is well suited for the purpose.

In *Pila*, where a very large amount of cellulose is digested extracellularly, the presence of a very powerful cellulase is of importance. This enzyme was first demonstrated by Bredeman and Moritz in *Helix pomatia*. Subsequently, it has been shown to exist in other Gastropods like *Helix aspersia*, *Pterocera* etc. In *Aplysia*, Howell (1939) found no cellulase in the gut fluid or in the extracts of the digestive gland, but by using a high concentration of the substrate with a suitable buffer, a weak action on filter paper was detected. The source of the cellulase in *Aplysia* and also in *Pterocera* has not so far been detected. In *Pila*, however, the extract of the digestive gland shows an active cellulase.

Summary

1. The structure and function of the digestive system of *Pila virens* are described chiefly with reference to the stomach and digestive diverticula.

2. Ciliary currents in the stomach of the animal have been studied and feeding experiments have been carried out employing substances like filter paper, Indian ink, iron saccharate, olive oil, boiled rice, sweet oranges etc.

3. *Pila* is a macrophagus, rhythmic feeding herbivore.

4. There is extracellular digestion in the stomach, the secretion of the digestive diverticula flowing into its lumen. In correlation with this feature œsophageal pouches are present.

5. The food-sorting mechanism in the stomach is described.

6. The cæcum plays an important role in the consolidation of undigested waste material into fæcal pellets.

7. The digestive enzymes have been studied, and besides other carbohydrases, cellulase is present, localised in the digestive gland. Proteases are lacking, but lipase is present.

Acknowledgment

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SEASONAL VARIATIONS IN THE TESTES OF *RANA TIGRINA*: THEIR INFLUENCE ON THE MIANINI PREGNANCY TEST

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The Mianini test has been established as a simple means for the detection of pregnancy. After an injection of 10 c.c. of urine of a pregnant woman into a male toad or a frog, spermatozoa appear in its urine usually within three hours and latest in 24 hours. This has been explained to be due to the detachment of spermatozoa from the cells of sertoli in the testes caused by the chorionic gonadotropin present in the pregnancy urine. Other conditions as hydatidiform mole, where a large amount of gonadotropin is excreted, also give positive results. The pituitary gonadotropins have similar action: Robertis, Burgos and Breyer (1946) demonststrated intense changes in the testes of toads—swelling, vacuolation etc. in the cells of sertoli, resulting in release of all the mature sperms within 10–30 minutes of injection of anterior pituitary extract.

Since Mianini (1947) demonstrated this simple test using the toad (*Bufo arenarum* Hensel), several species of toads have been successfully used as test animals, by many investigators. Many frogs *e.g. Rana catesbiana* (Olivella, Martell and Benach 1948), *Rana esculenta* (Anzar Ferrier, 1949) and *Rana tigrina* (Bhaduri and Bardhan, 1949 and Mukherjee and Saha, 1952) have also been found suitable for the tests. As a result of such widespread tests it is generally believed as Vigors Earle (1951) states that " almost any frog or toad could be used for the tests."

A preliminary investigation to test the suitability of local frogs for the pregnancy test was started in November 1950 in the laboratories of the Medical College, Baroda.

Material and Method

Mature males of *Rana tigrina* collected from Baroda and Bombay were used as test animals. The males were identified and kept in cages the previous evening or in the morning of the examination. Immediately before the test, urine was aspirated from the cloaca of the animal by a pipette bent at an angle about ½ cm. from the tip. The animal was accepted for the test only if its urine did not show any spermatozoa. Each animal was used only once. The sex was confirmed postmortem. Urine of only proved cases of pregnancy was used. In the first 20 cases the first morning samples of urine were used. Since such a collection was difficult to obtain, a morning sample, though not the first one, was accepted in other trials. Very dilute samples as seen from colour or specific gravity were rejected. The urine was stored in a cool place or refrigerator and injected within an hour of collection. Usually 10 c.c. of pregnancy urine was injected into the dorsal lymph sac with a 20 c.c. B.D. syringe sterilised by boiling. In some cases 15 and 20 c.c. of urine were injected in order to note whether a larger dose made any difference in the response.

Samples of urine from the injected animal were pipetted an hour after. Three or more coverslip preparations were examined for the presence of sperms. If the results were negative, fresh samples were aspirated hourly for the next two hours and examined. In case of the negative results again, further examination was made at the end of 24 and 48 hours. To confirm the negative results, urine from altogether 20 of them was centrifuged and then microscopically examined. Since none of them turned out to be positive, this procedure was abandoned afterwards.

Since a larger number of negative results were being obtained than reported by other workers, examination of the testes of 46 later experimented animals was conducted to find out the exact state of that organ in them. As the testes of some of the animals which had given the negative results failed to show spermatozoa in the fluid squeezed out from them or in their paraffin sections, the pregnancy test was not persued further ; but examination of the testes was carried out at random for the next 12 months. Their colour, size and weight, were noted and the fluid obtained after cutting them was examined microscopically and paraffin sections of some of these were also studied.

Results

Altogether 125 tests were performed with urine from proved cases of pregnancy during the period November 1950 to December 1951, (with the exception of March to June 1951) and in August 1953. Of these only 75 proved to be positive. Positive results were obtained in all months, but the incidence was more during the breeding season of the frog (June to August). Table I given below summarises the results :

Table I

Month		Total No. of examinations	Duration of pregnancy					
			1 to 3 months		3 to 6 months		6 to 9 months	
			positive	negative	positive	negative	positive	negative
November	1950	6	1	1	1	—	2	1
December	1950	3	—	—	—	—	3	—
January	1951	17	—	—	1	2	12	2
February	1951	8	—	—	—	—	3	5
March	1951	—	—	—	—	—	—	—
April	1951	—	—	—	—	—	—	—
May	1951	—	—	—	—	—	—	—
June	1951	—	—	—	—	—	—	—
July	1951	11	—	—	5	—	5	1
August	1951	19	1	—	2	3	6	7
September	1951	14	—	—	—	1	6	7
October	1951	4	—	—	1	1	—	2
November	1951	12	—	—	—	5	2	5
December	1951	6	—	—	1	—	—	5
August	1953	25	—	—	3	—	20	2
	Total	125	2	1	14	12	59	37

Most of the subjects whose urine was injected were 20 to 30 years old. The results were not related to their age or to the number of pregnancy or even to the weight of the animal used for the test. Nor were the results improved by injecting larger amounts of pregnancy urine. (*vide* Tables III, IV, V at the end). Repeating the test in 6 cases after concentrating the urine by the method described by Mukherjee and Saha (1952) and injecting it into the same frogs did not change the results. Of the 46 experimented animals whose testes were examined all the 20 positive cases showed spermatozoa in the fluid squeezed out from the testes after cutting them open, whereas sperms could be found in 20 out of 26 negative cases and were less abundant. No signs of sperms were found in the other six negative animals either in the testicular fluid or in their sections. Their smear preparations showed round bodies (? spermatids) instead of sperms. Subsequent study of testes examined at random showed that in the breeding season the testes were large, yellow-coloured, shining and filled with vigorously motile sperms. Such testes wieghed from 0·2 to 1·0 gm. During the dwindling season (February to April) the testes were small, sometimes negligible in size and weight, withered in appearance and bluish in colour. Even very large frogs in this season had very tiny testes. Spermatozoa, when present were less abundant and sluggish. When expressed the testes yielded tiny refractile droplets of fat and dark round bodies. Table II gives a statement of the results of examination of the testes of 128 specimens.

Table II

Months		No. of frogs examined	Spermatozoa		Percentage of positives
			present	absent	
February	1952	4	1	3	25%
March	1952	10	3	7	30%
June	1952	9	9	—	100%
July	1952	52	52	—	100%
August	1952	15	12	3	80%
September	1952	20	7	13	35%
October	1952	12	3	9	25%
November	1952	6	3	3	50%
Total	...	128	90	38	

Paraffin sections of positive testes obtained during the breeding season (June to August) showed sperms in various stages of development, as well as numerous clusters of mature sperms in the alveoli (Fig. I, 1). The alveoli showed regular rounded outline.

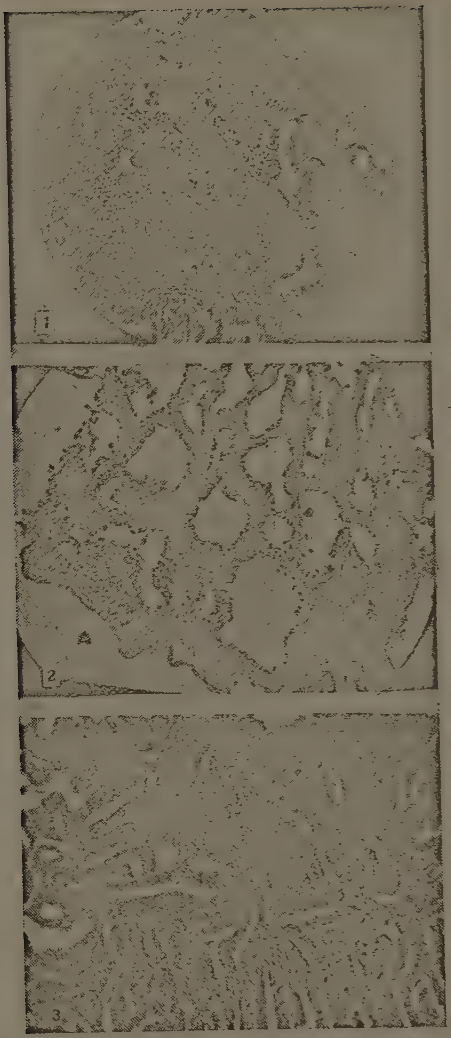

Fig. I. (1) Section of testis of *Rana tigrina* during the breeding season. (2) Section of testis immediately after breeding season. (3) Section of testis during the off season.

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Sections of testes in the months immediately following the breeding season showed sperms only in isolated alveoli, the vast majority of them being empty (Fig. I, 2).

Sections of testes in March showed an atorphied appearance of the alveoli with the germinal epithelium considerably folded. There were no signs of proliferation and the alveoli were irregular and shrivelled up. (Fig. I, 3).

Discussion

The Mianini test was tried with urine from proved cases of pregnancy by injecting it into *Rana tigrina* collected from Bombay and Baroda to see how far they responded to it, in view of the reported success by Bhaduri and Burdhan (1947) and by Mukherjee and Saha (1952), who employed *Rana tigrina* collected from Bengal. Analysis of125 trials listed in table I reveals that it was successful in 75 (*i.e.* 60% of the cases). This figure was far too low compared with 98·57% positives obtained in Bengal by Mukherjee and Saha.

Natural curiosity was aroused even during the course of the investigation when confronted with negative results and larger doses were tried. This procedure was not found to be of use either. The next step was to examine the state of the testes to ascertain the cause of the failure in some cases. The statistics of specimens examined as given in Table II reveal that the testes of almost all the frogs in the breeding months (June to August) contained mature spermatozoa. In the months following the breeding season the sperms were present in a majority of specimens. The paraffin sections of the testes in the breeding season are illustrative of the success obtained during that season. On the other hand, of the sections of the testes examined during the non-breeding season only a few showed spermatozoa. That the testes in frogs undergo recession during the non-breeding season is well-known. Glass and Rugh (1944) have reported the involution of the testes in *Rana pipiens*. Smith (1950) has recorded similar seasonal changes in *Rana temporaria*. He found the testis dwindling to half its weight after the breeding time and considerably more later on. In Bombay and Baroda where the weather conditions in between June to August and Janaury to March are in sharp contrast, it is no wonder that the testes of frogs undergo a recession during the latter period, after an active shedding of spermatozoa during the former one. It may be assumed that in those cases where a positive response is obtained during the off-season, spermatozoa linger on in the testes but it is not a sure natural condition. That the test will work with more reliable success only during the monsoon which is the breeding season for frogs, or after sensitising the tests by a suitable dose of gonadotropin previously, seems thus to be established. How the same species in Bengal gives uniform success in all seasons remains unanswered. It is suggested that in Bengal with its innumerable perennial water holds, *Rana tigrina* may be breeding throughout the year. An alternative suggestion is that these frogs in Bengal carry over a large reserve of sperms in the alveoli of their testes from one breeding season to the next.*

Summary and Conclusions

1. The Mianini test was tried with urine of 125 proved cases of pregnancy, using the male *Rana tigrina* collected from Baroda and Bombay. Only 75 out of 125 *i.e.* 60% showed positive results.

2. To find out the cause of the failure the testes of some of the tested animals and subsequently of others also were examined at random during the different months of the year. Mature sperms were found almost always in the breeding season in their testes but in the non-breeding season the storage of sperms was poor or totally absent. There was a marked difference between the testes of the breeding and the non-breeding seasons. In the latter it was very often atrophied with no evidence of spermatogenesis or storage.

3. It is suggested that the very high percentage of success obtained in Bengal throughout the year might either be due to the frogs breeding throughout the year or retaining a large store of sperms in their testes from one breeding season to the next.

APPENDIX

Table III

Analysis of tests para-wise

Para	Total No.	Positive	Negative
First para	30	15	15
Second para	19	14	5
Multi para	62	34	28
Unrecorded	14	12	2
	125	75	50

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* While this paper was in press, Rane, V. A. (*Journal of Obstetrics and Gynæcology of India*, 4, 2, p. 138-148, Dec. 1953) has reported that only 66% of the male frogs (*Rana tigrina* of Bombay gave positive results when employed for the Mianini test. He could, however, accurately diagnose pregnancy with 95.5% success in 325 cases by using 5 frogs for each pregnancy test and reading the test as positive even if one sperm was found in the urine of any one of the injected animals.

Table IV

Analysis of tests according to quantity of urine injected

Quantity of urine injected	In No. of frogs	Result	
		Positive	Negative
10 c.c.	97	65	32
15 c.c.	17	7	10
20 c.c. or more	11	3	8
Total	125	75	50

Table V

Weights of 66 frogs tested, selected at random

Weight of the frogs	Result of tests		Total
	Positive	Negative	
75 to 100 grms.	1	—	1
100 to 150 grms.	3	1	4
150 to 200 grms.	6	8	14
200 to 300 grms.	9	16	25
300 to 400 grms.	4	6	10
400 to 500 grms.	8	3	11
500 to 550 grms.	—	1	1
Total	31	35	66

Acknowledgment

I am indebted to Dr. J. C. George, Ph.D., Reader in Zoology, Faculty of Science, M. S. University, Baroda, for valuable suggestions and for confirming the identification of frogs; to Dr. Miss M. Varde, Ph.D., lecturer in Embryology, Medical Faculty, Baroda, for help in identification of the animals and preparation of sections; to Dr. A. N. de Quadros, F.R.C.S., D.P.H., Principal, Medical College, Baroda for permission to work and interest shown.

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ON THE LIVER FAT IN *PILA GLOBOSA* (SWAINSON)

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While examining the liver (the digestive gland) of the common apple-snail *Pila globosa*, we found that the main reserve material in that organ is fat and not glycogen. The storage of fat in certain animals for utilization in the production of eggs and sperms and also hibernation or æstivation is well known. *Pila globosa* æstivates during the dry months of the year commencing with end of January or beginning of February, and starts breeding with the onset of the rains in July. Eggs are laid in large masses of 200 to 800. George and George (1944) have noted the presence of a considerable quantity of fat in the digsetive gland of the crustacean *Paratelphusa* before it æstivates and they have made a report on the properties of that fat. We have not come across any such work on Molluscs and so it was thought proper to study the properties and seasonal variations in the quantity of the liver fat in this animal.

Method

The liver mass (after carefully removing the coils of intestine and parts of the reproductive system) from a number of fresh snails, was weighed and completely dehydrated in the electric oven at 80°C. From this material then extraction of fat was made by using the Soxhlet apparatus and the percentage of fat was estimated. Readings were taken for the different months of the year. The refractive index of the fat was determined by using Abbi's refractometer. For the determination of the saponification and iodine values, the methods suggested in the official and tentative methods of the American Oil Chemists Society were employed.

Results

Below is given the seasonal variations noted in the amount of fat in the liver of Pila for the year 1952-53.

Table I

Month	Sex of Pila	Average weight of pila	Average weight of liver	Average weight of liver fat	Weight of fat per 100 gm. of liver	Percentage weight of fat per animal
January	males	39.0	1.8562	0.2527	13.61	.64
	females	52.883	3.2510	0.3901	11.99	.73
February	males	38.560	1.7642	0.21170	12.00	.54
	females	50.382	2.7441	0.2777	10.12	.55

Table I—*contd.*

Month	Sex of Pila	Average weight of pila	Average weight of liver	Average weight of liver fat	Weight of fat per 100 gm. of liver	Percentage weight of fat per animal
March	males	38.993	2.869	0.1958	6.82	.50
	females	54.723	2.470	0.2102	8.51	.40
April	males	35.530	1.8331	0.0935	5.10	.26
	females	53.974	2.4288	0.1432	5.90	.24
May	males	34.123	1.7610	0.0729	4.14	.21
	females	54.313	2.5612	0.1063	4.15	.20
June	males	45.020	3.2268	0.1130	3.50	.25
	females	90.324	4.0644	0.1496	3.68	.16
July	males	40.431	1.5165	0.0715	4.71	.17
	females	45.520	1.8353	0.1125	6.13	.25
August	males	35.430	1.6461	0.0494	3.00	.14
	females	47.638	1.704	0.07024	4.12	.15
September	males	33.822	2.082	0.0476	2.69	.15
	females	40.8	2.291	0.8450	3.825	.21
October	males	37.747	1.9925	0.170	8.53	.48
	females	42.642	1.8762	0.1388	7.40	.32
November	males	43.842	2.12	0.271	12.78	.61
	females	68.931	3.8006	0.3740	9.84	.54
December	males	40.540	1.6152	0.2101	13.00	.50
	females	88.185	4.1475	0.4148	10.00	.44

Table 2

The table given below gives the refractive index, iodine and saponification values of the fat of Pila globosa.

Refractive index	Iodine value	Saponification value
1.4830 at 40°C.	60.10	144.539

Discussion

The increase of liver fat takes place from October to January-February. From March onwards there is a reduction of liver fat till September. From March to July the animals æstivate and there is no doubt that they utilize the stored up fat at that time. That accounts for its progressive reduction during that period. Though July to September is an active feeding period, fat deposition does not take place in the liver there. This can easily be accounted for. It is during these months that the gonads develop and both sperms and ova are formed and there is no surplus material to be stored up as reserve.

The saponification and the iodine values for the muscle fat of *Palæmon* and *Panulirus* have been determined by George and Shah (1953). The saponification values for *Palæmon* and *Panulirus* are 148·609 and 156·230 respectively and the corresponding value for *Pila* is 144·539, which comes closer to that of *Palæmon*, which is also a fresh-water animal. The iodine values of the fat of *Palæmon* and *Panulirus* are 113·584 and 119·050 respectively, while that of *Pila* is only 60. This means that the fat of *Pila* contains relatively more saturated fatty acids.

Summary

The main material in the liver of *Pila* is fat and not glycogen. There is a great deal of Seasonal variation in the fat content of the liver in both the sexes. It is at its maximum in January and minimum during September. It is utilized for providing energy during æstivation and in the production of eggs and sperms.

The refractive index of the liver fat, saponification and Iodine values of the *Pila glubosa* are respectively 1·4830, 144·539 and 60·10. The first two figures compare favourably with those of crustacean liver fat. For example those of *Paratelphusa* are respectively 1·485, 178-192, and 90-115.

Acknowledgment

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A COMPARISON OF THE AMINO-ACID CONSTITUTION OF THE SCALES OF *VARANUS MONITOR* LICHENSTEIN AND *CALOTES VERSICOLOR* DAUDIN AND THE FEATHERS OF *COLUMBA LIVIA* GMELIN

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BECAUSE of many similarities reptiles and birds are sometimes grouped together to form the Sauropsida. Such a classification, however, is not generally favoured, though it is recognised that birds are descended from the reptiles. In this evolutionary stride scales are supposed to have been evolved into feathers. But little is known about the origin of feathers, though it is speculated that the feather is an elaboration of the scale frilled for most of the length except at the base. De Beer on the other hand opines that ' From the study of the feathers and scales of the leg of the ostrich there is reason to believe that feathers were evolved in connection with scales, but not from them.' As a considerable part of the scales of reptiles and the feathers of birds is made up of nitrogenous substances, it was thought advisable to find out their amino-acid constitution and also their total nitrogen, to see if the results would throw some light on the origin of the latter.

The common lizards *Varanus monitor* and *Calotes versicolor* were selected as representatives of reptiles and the pigeon *Columba livia* of birds and the scales of the first two and the feathers of the last were subjected to the investigation detailed below.

Experimental

The usual technique for paper chromato graphic determination of amino-acids was employed for the qualitative analysis of the nitrogenous substances of the scales and feathers. The total nitrogen in them was estimated by the classical Kjeldhal's method.

Results

The following amino-acids were common to both the scales and the feathers :— Leucine, Phenylalanine, Methionine, Valine, Tyrosine, Proline, Alanine, Glutamic acid, Threonine, Glycine, Serine, Arginine, Histidine, Lysine, and Cystine. There was indication that Calotes scales contained one more amino-acid which was not identified. The figures of total nitrogen are as follows :—

	gm. per 100 gm. of dry weight
Scales of Varanus	13·53
Scales of Calotes	14·20
Feathers of Columba	16·50

Discussion

It can be seen from the results obtained that qualitatively the amino-acid composition of both scales and feathers tested was almost identical. Since both scales and feathers are derivatives from the ectoderm, this result could be anticipated. It follows therefore that both scales of lizards and feathers of birds are morphologically and chemically similar, though they serve diverse purposes in their owners. The higher percentage of total nitrogen in the feathers indicates quantitative difference in amino-acids between them and scales. There is no chemical evidence to suggest that feathers are not modified scales.

Acknowledgment

I am extremely thankful to Principal Thomas Barnabas for providing all facilities for me to undertake the investigation. My thanks are also due to Mr. M. C. Badve for his invaluable help which alone made it possible for me to complete the investigation successfully.

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A NOTE ON THE MUSCLE FAT OF THE LOBSTER *PANULIRUS POLYPHAGUS* (HERBST) AND THE PRAWN, *PALÆMON CARCINUS* (HENDERSON AND MATHAI)

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ONLY meagre reports are available on the properties of Crustacean muscle fat. Below is given the refractive index, saponification value as well as the iodine value of two decapod crustaceans the first marine, and the other freshwater.

Table showing certain properties of the fats :—

Name	Refractive index	Iodine value	Saponification value
Panulirus polyphagus ...	1·4590	119·050	156·230
Palæmon carcinus	1·4492	113·584	148·609

Though the two decapods inhabit diverse habitats, there is not much difference in the nature of their muscle fat.

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A COMPARATIVE STUDY OF THE BLOOD VOLUME IN THE CRUSTACEANS *SCYLLA SERRATA*, *PANULIRUS POLYPHAGUS* AND *PARATELPHUSA GUERINI*

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THE efficiency of a closed circulatory system can be considered to depend upon the frequency with which the heart beats, the extent of its blood vessels and the volume of blood that fills them all. In any group of animals with a closed blood-vascular system, the more elaborate its system of blood vessels, relatively more the quantity of blood. Thus in the vertebrates the birds and mammals have more elaborate blood-vascular systems and therefore their blood volume is more than that of others. This relation does not, however, hold good for those animals with a hæmocoelic system, since they possess no separate lymphatic system, the latter having merged with the blood system. These animals naturally should possess a greater amount of the so-called blood than the others with separate blood and lymph systems. In them the systolic pressure exerted by the heart will be considerably reduced in the hæmocoel. The compensation for that is the large blood volume without which a hæmocoelic vascular system may not work.

It is believed that the quantity of blood is more or less maintained constant in an animal, although often it is subjected to variations due to many causes. It is maintained constant by adjusting the interchanges between the plasma and the tissue fluids and by regulating the flow of fluids from the body to the outside.

This paper deals with the blood volume of three crustaceans *Paratelphusa guerini*, *Scylla serrata* and *Panulirus polyphagus* occurring in Bombay. The most significant recent paper on the subject is by Prosser and Weinstein (1950) on the blood volume of the Crustacean *Cambarus virillis*.

Procedure Adopted : The following procedure was found quite satisfactory :—

The animal was first weighed alive. 250 mg. of congo red were dissolved in 100 c.c. of 0·9% sodium chloride solution and exactly 0·5 c.c. of it was taken in a graduated syringe with a fine needle. A small pin-hole was made on the carapace of the living animal in the region of the pericardial sinus. The dye was injected into the circulation through this pin-hole with the help of a syringe. The needle was manipulated in such a way that the dye was introduced into the pericardial sinus. After delivering the dye into the circulation the needle was carefully withdrawn and the finger pressed against the pin-hole for some time to prevent bleeding, 4 to 5 minutes were allowed for the complete mixing of the dye with the blood. During this interval the animal was made to move about, so as to stimulate circulation. Then the blood was extracted with the help of a syringe and transferred into a graduated centrifuge tube containing sufficient quantity of potassium oxalate (0·5 c.c. of 10% solution) in the form of a thin dry film. The tube was tightly corked and the volume of blood noted. It was then centrifuged. This led to the separation of corpuscles and plasma into distinct layers. The volume of corpuscles was noted and the plasma was transferred to another tube with the help of a pipette. 0·5 c.c. of the plasma was then measured into a graduated tube and made up to 5 c.c. with normal saline. A standard was prepared with 20 c.mm. of the dye made up to 5 c.c. with 0·5 c.c. of plasma from another living animal and the rest of normal saline. The unknown was then compared against the standard in the Klett-Summerson Photo-electric Colorimeter setting it to Zero density with a blank prepared with 0·5 c.c. of plasma made up to 5 c.c. with normal saline. A green filter was used in the colorimeter. From the extent of dilution of the dye injected, the total volume of plasma was calculated. Knowing the plasma to corpuscle ratio in the blood, the total volume of blood was determined. The volume divided by the weight of the body gave the amount of blood per gram weight of the body.

Results

The following are the blood volumes obtained in the three crustaceans tested :—

Paratelphusa guerini ...	27·87 c.c. per 100g. body weight.
Scylla serrata	12·73 c.c. per 100g. body weight.
Panulirus polyphagus	17·02 c.c. per 100g. body weight.

Discussion

Prosser and Weinstein (1950) found that the blood volume of *Cambarus virilis* to be 25·6 c.c. per 100g. of body weight. Nagel (1934) found the blood volume of *Carcinus* to be 37 c.c. per 100 g. of body weight. The figures obtained by me were in the case of *Paratelphusa* 27·87, in *Panulirus* 17·02 c.c., in *Scylla* 12·73 c.c. for 100g. body weight. Thus there is a wide range of variation of blood volume in the decapod crustaceans. The larger blood volumes must be in some way related to the mode of life of their possessors. *Paratelphusa* is a freshwater crab which peregrinates out on land for prolonged periods and perhaps the larger blood volume as in *Carcinus* may be meant as a storehouse of oxygen.

The vertebrates have as a rule a low blood volume ; the values given by Menon are *Rana tigrina* 7·59 c.c., *Uromastix* 4·37 c.c., *Columba* 12·9 c.c. and *Rattus* 7·6 c.c. per 100g. of body weight. The highest here is in the case of the pigeon and it compares favourably with that of the crab *Scylla*. They are, however, similar for two different reasons. In the former the blood volume is correlated with the higher energy output of the animal, while in the latter it is meant to compensate the stagnation of blood consequent on the break-down of the capillary system.

Summary

1. The following are the respective amounts of blood per 100 g. weight of the body, in *Paratelphusa* 27·87 c.c., in *Panulirus* 17·02 c.c. and in *Scylla* 12·73 c.c. per 100 g. body weight. The crustaceans examined possess larger blood volume than the vertebrates. The significance of a large blood volume is discussed.

2. Of the three crustaceans examined, *Paratelphusa guerini* has the largest blood volume. This may have some bearing on the fact that this animal is partly terrestrial in its habits.

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THE GLUCOSE AND FAT LEVELS IN THE BLOOD OF FIVE REPRESENTATIVE VERTEBRATES

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APART from fixing oxygen, the blood performs the function of transporting food materials (glucose, amino-acids, neutral fats, fatty acids, glycerides). These are to be regarded as substances in transit from the digestive organs to the organs of storage or to the tissues of the body in which they are utilized.

The amount of glucose in the blood of invertebrates is generally very small and a definite regulation of sugar level seems to be lacking in most cases (Florkin, 1949).

In the vertebrates glucose is maintained in the blood at a constant level and there is a glycogen store in the liver from which it is converted into glucose as and when the sugar level falls in the blood. The regulation of blood sugar at a constant level seems to have greatly increased the ability of a vertebrate to exercise its muscles whenever so needed, since blood sugar can be readily utilized to replenish the muscle with muscle-glycogen which is used up in contraction. A determination of the blood-sugar level in representative vertebrates is regarded likely to throw light on the readily-available energy resources in their blood. Moreover, the differences if found are likely to be of evolutionary significance.

Very little has been known about the part played by fat in the contractile mechanism of the muscle. It is known in this connection that the blood leaving a working muscle contains less fat than the blood entering it (Lafon, 1913). The results obtained by Zuntz (1911) and those of Benedict and Cathcart (1913) show that fats and carbohydrates are both equally well utilized in the production of muscular activity. It appears that muscular work can be carried out for long periods with fat as the principal source of energy, though a certain amount of glucose seems to be absolutely essential. As fats are readily convertible into glucose, the total amount of glucose and fat in the blood might indicate a correct energy potential of the animal. Both these have therefore been estimated in the blood of five representative vertebrates.

Experimental

Glucose.—The method of Folin and Wu (1920) has been used for the estimation of glucose in the blood. The protein-free filtrate of blood was heated with alkaline copper sulphate solution using a specific tube to prevent reoxidation. The cuprous oxide formed was treated with phosphomolybdic acid solution, when a blue colour was obtained which was compared with that of a standard in a colorimeter, to obtain the required figure.

Fat.—Fat in the whole blood was determined by the ether extraction method after drying it on sodium sulphate for ten minutes in an air oven at 100°C.

Results

The following table gives mean values of estimates of glucose and fat in the blood of five representative vertebrates.

		Glucose	*Fat*
Fish	*Macrones gulio*	35·7 mg.	0·6 gm. per 100 cc. of blood
Amphibian	*Rana tigrina*	33·5 ,,	0·17 gm. ,,
Reptile	*Uromastix hardwickii*	133 ,,	0·47 gm. ,,
Bird	*Columba livia*	208 ,,	1·76 gm. ,,
Mammal	*Rattus rattus*	103·5 ,,	0·23 gm. ,,

Discussion

A comparison of the results shows that the amount of glucose in the blood is highest in the pigeon among the animals tested. It is known that the blood-sugar is high in birds (Erlenbach cited by Scheer). This is to be expected as the flight muscles of birds require a considerable amount of ready energy—giving material in order to enable them to do the strenuous job of flight. At least in the initial stage of flight when sudden action is required of the muscle, large amount of glucose must be utilized and therefore the blood sugar level should be necessarily high. The highest percentage of fat is also found in the pigeon blood. George (1952) and Nair (1952) have shown that the breast muscles of birds contain a large amount of fat and the percentage of fat present has a direct relation to the ability of the bird for sustained flight. The fat present in the muscle must find its way there via the blood stream, and in order to conserve and maintain so much fat in the muscular tissue, the fat level in the blood must also be maintained high. The combined value of fat and glucose is also highest in the bird among the animals tested.

The amount of glucose present in the blood of rat is 103·5 mg. per 100 c.c. *Uromastix* shows a higher amount (133 mg.) and it is to be found out if the figure represents a Lacertilian level. One important factor has to be taken into account in examining this issue. *Uromastix* is a highly excitable animal and it may be quite possible that this high value has been found as sugar was thrown into the blood due to the excitement caused by handling.

The fat figure is also high in *Uromastix*. It should be noted in this connection that at the time of estimating fat (December-January) the fat bodies of this animal were being built up and the higher value might be a seasonal one and not a normal feature. Since *Uromastix* is an animal which lives in excessively dry regions, the storage of fat will serve as a measure of water conservation, since fats when oxidised yield more water than glucose.

The amount of glucose in the blood of *Macrones* is 35·7 mg. per cent, whereas in the frog it is 33·5 mg. *Macrones* is capable of living outside water for 3 to 4 hours. It has been found that the blood sugar level increases when kept out of water. Value as high as 120 mg. per 100 c.c. of blood has been obtained in this fish once after a period of exposure, and low values have been consistently found when the blood was drawn without exposure to air. The figure of 35·7 mg. therefore does not seem to be a normal one.

The fat value for *Macrones* is considerably higher than that of the frog. As in the case of *Uromastix* fat may serve as a source of water on oxidation for this marine animal.

It is interesting to note that in the invertebrates the glucemic level is low in most animals and that it is higher in the vertebrates. In the Elasmobranch *Scyllium canicula* it is given as only as 20 mg. per 100 c.c. (Florkin 1949). The higher figures obtained in the case of the five representative vertebrate types indicate that there seems to be a tendency to increased sugar toleration in the blood in accordance with the evolutionary status of the group to which each of the types belongs. A personal factor other than the evolutionary status seems to operate in the case of *Uromastix* to give its blood a higher sugar-level. Only a more extensive study can throw more light on the problem.

There seems to be no indication of progressive increase in fat content of the blood from fishes to birds and mammals.

Summary and Conclusions

1. The amount of glucose and fat present in the blood of five representative vertebrates was determined.

2. The figures obtained seem to indicate a tendency to increased sugar-level toleration in the blood from the lower to the higher vertebrates.

3. On the other hand, the amount of fat in the blood appears to be in correlation with other factors especially the activity of the animal, and does not seem to reflect its evolutionary level.

Acknowledgment

I am in duty bound to record my deep sense of gratitude to Dr. C. J. George for his constant guidance and encouragement during the investigations. My thanks are also due to the authorities of the Wilson College, Bombay, for affording facilities for carrying out the work.

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A COMPARATIVE STUDY OF THE CHEMICAL COMPOSITION OF THE MUSCLE OF THE LOBSTER *PANULIRUS POLYPHAGUS* (HERBST) AND THE PRAWN *PALAEMON CARCINUS* (HENDERSON AND MATHAI)

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THE nutritive values of some of the marine prawns of Bombay have been estimated by Appana and Devadatta (1942) and those of the Calicut coast by Chari (1948). Gopal Krishnan (1951) has estimated the water, solids and fat contents of some of the prawns of the Madras Coast. Very few papers are available on the chemical composition of the freshwater representatives of the Decapoda. Nor has similar work been done on the lobster *Panulirus* which is studied as a type animal in the Universities of Western India. It was therefore thought desirable to work out the gross chemical composition of the muscle of the lobster *Panulirus polyphagus* and the freshwater prawn *Palæmon carcinus.*

Method

The protein content was estimated by means of the Klett Summerson Photoelectric Colorimeter adopting a modified Wong's method. Fat was extracted by ether using a Soxhlet apparatus and weighed after evaporating the ether. The amount of carbohydrates was calculated by subtracting the amounts of fat, proteins and ash from the total solids. By multiplying the figures obtained for proteins, fat and carbohydrates by their respective standard energy values 4·1, 9·3, and 4·1, calories, and then by adding them up, the total energy value for 100 gm. of muscle was determined.

Results

The table given below summarises the results obtained.

Table showing the chemical composition of 100 gms. of muscle and nutritive value of 100 gm. of muscle of *P. polyphagus* and *Palæmon carcinus*.

Name		Water	Total Solids	Proteins	Fat	Ash	Carbo-hydrates	Nutritive value in calories per 100 gm. of muscle
Panulirus polyphagus	...	75.480 %	24.520 %	19.0 %	1.03 %	1.097 %	3.393 %	101.390 %
Palæmon carcinus	...	71.250 %	28.750 %	23.0 %	0.83 %	0.753 %	4.167 %	119.103 %

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THE BEARING OF THE WEIGHT OF THE PECTORAL MUSCLES ON THE FLIGHT OF SOME COMMON INDIAN BIRDS

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THE wings of a bird must have sufficient power. This power is contributed mainly by the pectoral muscles—the *pectoralis major* and the *pectoralis minor.* The amount of muscle substance indicated by the weight of these muscles reflects the power available. The muscle power of different species of birds can be compared by ascertaining the relation between the pectoral muscle weight and the body weight. That this is so had been acknowledged by earlier workers like Marey (1874), Magnan (1921), Gladkov (1937), Smith (1938), and Storer (1940). While the amount of muscle substance is a gross estimate, their chemical composition reveals the amount of convertible energy available in them. A discussion on the chemical composition of the pectoral muscles has been published in an earlier paper (Nair, 1952).

This paper discusses the significance of the weights of the pectoral muscles in relation to body weight in some common birds comprising the three types of flight *viz.* flapping, shooting and soaring and also the poor and non-fliers. The birds dealt with in this paper are the same as those mentioned in that paper entitled 'The wing-spread and its significance in the flight of some common Indian birds' (George and Nair, 1952). In the first group are included the Rock-Pigeon (*Columba livia*), the Rose-ringed Parakeet (*Psittacula krameri*), the House-Crow (*Corvus splendens*), the Grey Partridge (*Francolinus pondicerianus*) and the Pin-tailed Duck (*Dafila acuta*). The second group is represented by the House-Sparrow (*Passer domesticus*), while the third by the Pariah Kite (*Milvus migrans*). The fourth group comprise the poor flier, the Domestic Fowl (*Gallus domesticus*) and the Domestic Duck (*Anas platyrhyncha*) which makes no effort to fly. Below is given in Table I the type of flight, weights of the *pectoralis major* and the *pectoralis minor* respectively per unit weight of the body and also the buoyancy index of each bird :—

Table I

Name of the bird	Type of flight	Weight of the pectoralis major per unit weight of the body in gm.	Weight of the pectoralis minor per unit weight of the body in gm.	Buoyancy index
Crow	flapping	0·1142	0·0102	5·005
Parakeet	do.	0·1401	0·0299	3·662
Partridge	do.	0·1597	0·0520	3·370
Pigeon	do.	0·1847	0·0318	3·954
Pin-tailed duck ...	do.	0·1928	0·0289	2·958
Sparrow	Shooting	0·1441	0·0178	3·785
Kite	Soaring	0·1765	0·0078	5·274
Domestic fowl ...	poorly-flying or non-flying	0·0393	0·0245	3·213
Domestic duck ...	do.	0·0582	0·0115	2·708

Discussion

Pectoralis major.—It is apparent from the figures given in the table that the primary factor responsible for the inability of the domestic fowl and the domestic duck to indulge in sustained flight is lack of muscle power.

Magnan (1921) has enunciated a general principle that in birds the motor power varies inversely to the surface area of the wings, and he maintains that the birds which are indisputably the best fliers have the weakest motor power and the greatest wing surface. The figures given above show that his generalisation has validity within certain limits only. This should naturally be expected, since the needs of the various types of flight are different and also the deployment of this muscle power in the various types is also different ; and as such a common principle can hardly be present in all. Though there exists a somewhat inverse relation between the surface area of the wings and the muscle weight in certain cases, it need not always be that the bird with the largest wing area shoud possess the weakest motor, for example the kite listed in this paper has the highest buoyancy index, at the same time possesses a value of 0·1765 for the *pectoralis major*, which is much more than what is found in the crow, parakeet or partridge. Smith (1938) has drawn the general conclusion that the sailing birds have the minimum pectoral muscle weight. This also seems to be an unwarranted conclusion, since the kite possesses a value 0·1765 (17%) which is more than that of the Mallard (14·6%,) a flapping flier, as listed in his table. During soaring and gliding the wings are partially depressed, and they are kept in that position throughout the flight.

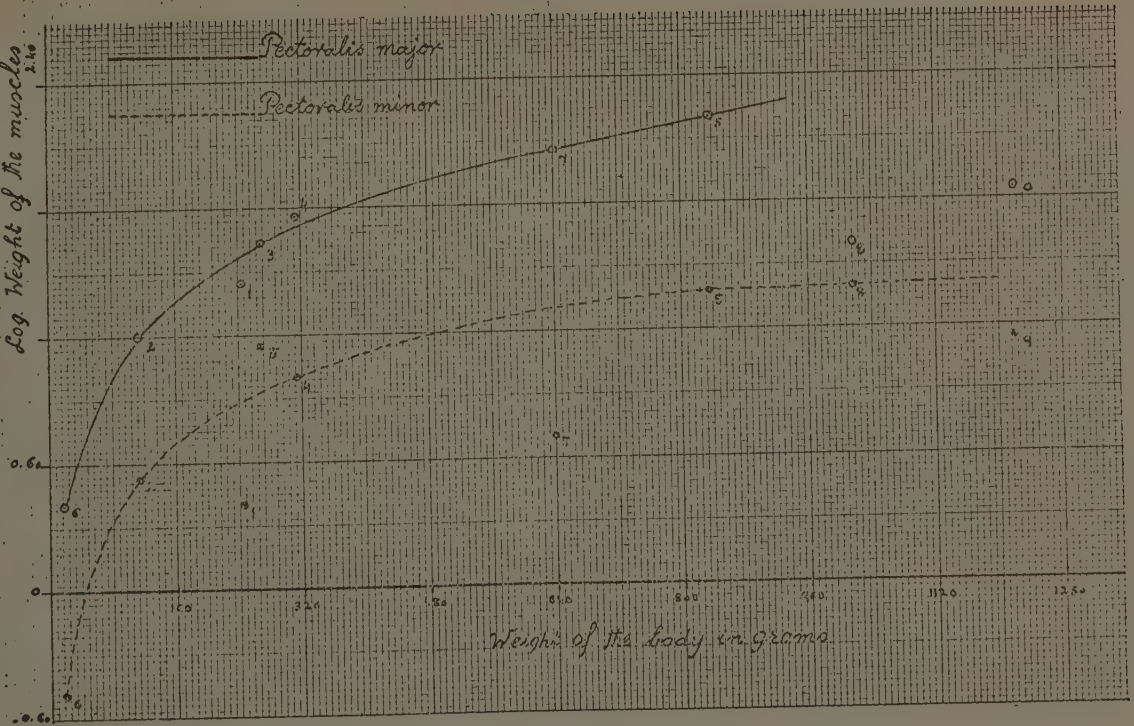

Fig. 1. Graphs showing the relation between the weights of (1) the *pectoralis major* and (2) the *pectoralis minor* and the body weights in some Indian birds (for names of the birds indicated by numbers in the graph above, refer Table II, page 75).

Hence the *pectoralis major* will be in a state of tonic contraction; otherwise the pressure below the wings might cause a sudden elevation of them. This will certainly interfere with the smooth flight of the bird. The high value in this case can be well explained on that score.

Among the birds of the flapping group, the crow flies by means of slow wing-strokes of small amplitude, while the pin-tailed duck flies with rapid wing-strokes of higher amplitude. This is quite in accordance with their respective values for the muscle weight, 0·1142 for the crow and 0·1928 for the pin-tailed duck. Taking the birds of the flapping group alone into consideration, it may be said that there exists a direct relation between the muscle weight on one hand and the frequency and amplitude of the wing-strokes on the other.

The sparrow which belongs to the shooting type has a value of 0·1441. The frequency of the wing-stroke is 13 (Aymar, 1936). This high rate seems to be essential for this bird if it has to make any progress in flight, since the viscocity of the air affects this bird more than any other under discussion, since it is very light.

Pectoralis minor.—The domestic fowl and the domestic duck have values 0·0245 and 0·0115 respectively, which are higher than those obtained for some of the flying birds listed here. These values show that the *pectoralis minor* does not seem to have degenerated, at least in weight, as much as the *pectoralis major* of these birds. Hence the inability for sustained flight in these birds appears primarily to be due to the degeneration of the *pectoralis major*.

Among the birds under dicussion the lowest value is for the kite. It, being a soaring bird, does not indulge in a continuous flapping flight. It does so only when it takes off from a place, or during early morning and late evening hours when there are rarely any air currents in the atmosphere. Moreover this muscle plays only a minor part in the soaring and gliding flight of this bird. Hence a smaller *pectoralis minor* is no handicap for the kite.

Comparing the values obtained for the other birds, it is seen that the inverse relation between the muscle weight and the wing area, noted by Magnan (1921) for the *pectoralis minor* also does not seem to exist in all the cases.

Two graphs, one for the *pectoralis major* and the other for the *pectoralis minor*, depict the relation between the body weight and the muscle weight. The body weights were plotted against the logs of the weights of the *pectoralis major* and the *pectoralis minor*. The graph obtained in the case of the *pectoralis major* shows that the points for the domestic fowl and the domestic duck fall very much below the line obtained by connecting the points obtained for the rest of the birds (Fig. 1).

Since, in the case of the *pectoralis minor*, the points for the poorly-flying and the non-flying types fall in line with those of the majority of the flying types, it may be said that flight is conditioned more by the muscle power of the *pectoralis major* than that of the *pectoralis minor.*

Summary and Conclusions

1. The relation between the pectoral muscle weight and the body has been determined in some common birds.

2. The values obtained for the domestic fowl and the domestic duck are the lowest in the series. This low value seems to be one of the factors responsible for the inability of these birds to indulge in sustained flight.

3. Since the kite has a higher value for the *pectoralis major* than those of some of the flapping fliers, it follows that the muscle weight of the *pectoralis major* need not necessarily be low for all soaring birds as contended by some previous workers.

4. The relation between the muscle weight and the wing-spread is not always an inverse one for all the birds as postulated by others.

5. Since the values for the *pectoralis minor* in the domestic fowl and the domestic duck are higher than those obtained in some of the flying birds, it can be said that the lack of muscle power in the *pectoralis major* is mainly responsible for their inability to indulge in sustained flight.

Table II

A table giving the body weights and the weights of the muscles pectoralis major and the pectoralis minor in some Indian birds

No.	Name of the bird		Weight in gm.	Weight of the pectoralis major in gm.	Log of the weight of the pectoralis major	Weight of the pectoralis minor in gm.	Log of the weight of the pectoralis minor
1.	Crow ...	...	245	28	1·4472	2·5	0·3979
2.	Parakeet ...	...	113	16	1·2041	3·4	0·5315
3.	Partridge ...	...	269	43	1·6335	14	1·1461
4.	Pigeon ...	...	314	58	1·7634	10	1
5.	Pin-tailed duck	...	836	160	2·2041	24	1·3802
6.	Sparrow ...	...	18	2·54	0·4048	0·322	1·5079
7.	Kite ...	...	639	113	2·0531	5	0·6990
8.	Domestic fowl	...	1017	40	1·6021	25	1·3979
9.	Domestic duck	...	1220	71	1·8513	14	1·1461

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THE PHYSIOLOGICAL LAG OF THE DOMESTIC FOWL

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Unlike most birds the domestic fowl runs about freely, but does not fly from place to place. Nair (1952) worked out the gross chemical composition of the flight muscles of a group of birds, and pointed out as a result of the study, the organic deficiency in the wing muscles of the domestic fowl as one of the causes of its inability to perform sustained flight. This physiological insufficiency noted in the flight muscles is not to be taken as an isolated feature; related physiological conditions must be present in other tissues also. This note deals with the lag in the blood.

Elsewhere in this issue of the *Journal* the junior author has given the glucose and fat levels in five representative vertebrates. The avian type dealt with in that paper is the pigeon, the glucose and fat levels of which in 100 c.c. of blood are reported to be 28 mg. and 1·76 gm. respectively. The corresponding figures for the domestic fowl worked out by us are 160 mg. and ·38 gm. respectively. These figures are nearer similar ones found in the lizard type, for the values of glucose and fat in the blood of *Uromastix hardwickii* are 133 mg. and ·47 gm. respectively.

The natural conclusion that can be drawn from the illuminating contrast between the blood of the pigeon and the domestic fowl is that the inability of the latter to fly about like most birds is conditioned also by the insufficiency of glucose and fat in its blood stream.

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THE OXYPHORIC CAPACITY OF THE BLOOD IN FIVE REPRESENTATIVE VERTEBRATES

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It is presumed that in the evolution of vertebrates the oxyphoric capacity of the blood has progressively increased. Sufficient reliable data, however, are not available to substantiate this belief and also regarding the extent to which this trait has been stepped up from fish to bird and mammal. This paper gives the data obtained by studying the blood of five representative vertebrates, one from each class.

The oxyphoric capacity of blood is dependent on the amount of corpuscles, the quality of the hæmoglobin and also its amount in the corpuscles. Since hæmoglobin is enclosed in cells in vertebrates, the amount of corpuscles in the blood is a rough indication of its oxyphoric capacity.

The iron content in the blood is indicative of a different state of affairs. Since the amount of oxygen that can be fixed by the blood is dependent on its iron content, the amount of iron in the corpuscles is an index of the hæmoglobin concentration.

Experimental

The percentage of corpuscles by volume in the blood was estimated by centrifuging known volumes of blood in graduated centrifuge tubes, gently at first and then at a speed of 3000 revolutions per minute, for sufficiently long time till the corpuscles settle down and get tightly packed. The volume of corpuscles was read off on the tube and later on percentage was calculated.

The amount of iron in the blood was estimated by the method of Kennedy (1927). The entire amount was converted into the ferric state by heating with sulphuric acid and an oxydizing agent—perchloric acid. Thiocynate was then added which combines with ferric iron to form a compound $Fe(CNS)9KCNS\ 4H_2O$. The colour of this compound is red and the intensity of the colour developed is proportional to the amount of iron present. So the iron content was determined by colorimetric comparison.

Results

The following table gives mean values of determinations of (1) the amount of corpuscles in 100 c.c. of blood, (2) the amount of iron in 100 c.c. of blood and (3) the amount of iron in 100 c.c. of corpuscles.

Group of the animal	Name	Volume of corpuscles in 100 cc. of blood	Iron in 100 c.c. of blood	Iron in 100c.c. of corpuscles
Fish	*Marcrones gulio*	21·3 c.c.	33·4 mg.	157 mg.
Amphibian	*Rana tigrina*	22·6 c.c.	26·6 mg.	119 mg.
Reptile	*Uromastix hardwickii*	33·5 c.c.	32·2 mg.	113 mg.
Bird	*Columba livia*	37·0 c.c.	43·7 mg.	117 mg.
Mammal	*Rattus rattus*	38·8 c.c.	52·4 mg.	135 mg.

Discussion

Hall and Gray (1929) postulated that the higher concentrations of hæmoglobin in Mackerel and Bonito was traceable to their fast-moving and migratory habits. From similar observations they made the general remark that " The hæmoglobin concentration in marine fishes is perhaps an index of their physiological activity." Hall and Gray also found that elasmobranchs had very much less amount of hæmoglobin in their blood than teleosts. Redfield (1933) in his survey indicates that the oxyphoric property of elasmobranch blood is lower than that of teleosts. Elasmobranchs are now believed to be genetically unrelated to the teleosts and the lower amount of hæmoglobin in their blood cannot therefore be said to be due to their being lower fishes. From his survey Redfield hints at the following general conclusions :—(1) In general there is an increase in the O_2 capacity of blood, the higher vertebrates (birds and mammals) having up to 20 volumes. (2) The volume of corpuscles tends to increase towards the higher evolutionary series. (3) The concentration of hæmoglobin in the erythrocytes increases in the higher vertebrates with the highest values in reptiles, birds and mammals.

The investigation which forms the subject-matter of this paper though confined only to five representative forms was aimed at finding out whether there occurs a progressive increase from fishes to birds and mammals in the following respects :—

(1) In the corpuscle content of the blood.

(2) In the oxyphoric capacity of the blood measured in terms of iron content in 100 c.c. of blood.

(3) Hæmoglobin concentration in cells measured in terms of iron content of 100 c.c. of cells.

On account of the variations that exist between members of the same order as shown by Redfield from the figures so far available, the results obtained by me cannot be used to arrive at any important or reasonable conclusions. As regards the corpuscle content of the blood Redfield's figures are Fishes 15·5-41, Amphibians 14-41, Reptiles 9·8-24, birds 36-54 and mammals 29-46. In the five vertebrates examined by me the figures obtained are illustrative enough to confirm the general conclusions arrived at by Redfield, though he quotes lower figures in the reptiles.

With regard to the oxyphoric property of the blood measured in terms of mg. of iron in 100 c.c. of blood, the present values support the observations of Redfield only with reference to birds and mammals. On the other hand there is a marked recession in this respect from fish to amphibian. Though there is an increase from amphibian to reptile, the reptilian figure is less than that of the fish. From reptile to bird there is a sharp jump and still more to the mammal. In contrast to these, Redfield quotes very low values in fishes and reptiles.

A comparison of the hæmoglobin concentration in cells estimated in terms of the amount of iron in 100 c.c. of corpuscles shows that the reptilian blood has the lowest value, followed by that of the bird, amphibian, mammal and finally the fish. Little information is available from previous literature as regards the relative efficiency of hæmoglobin in the various vertebrate classes, though Redfield has mentioned that hæmoglobin concentration in erythrocytes increases from fishes and amphibian to the higher vertebrates. If Redfield's remarks are errrect, more iron should be found in 100 c.c. of corpuscles as we proceed from fish and amphibian to bird and mammal. Assessed by the present figures it does not appear so. If these figures reflect a correct state of affairs, the lowest amount of hæmoglobin is met with in the reptile and highest in the fish, with that of the mammal being mid-way between and that of the amphibian and bird slightly more to that of the reptile. Redfield's O_2 capacity figures are fishes 23-29, frog 33, turtles and crocodiles 29-48, pigeon 40 and rat 40. From the general trend it appears that the high value obtained by me in *Macrones gulio* does not seem to be general in fishes.

Summary and Conclusions

1. The volume of corpuscles in 100 c.c. of blood in five representative vertebrates was ascertained. The values obtained show that there is a progressive increase in the amount of corpuscles from fish to bird and mammal.

2. The amount of iron in 100 c.c. of blood, considered as an index of its oxyphoric capacity in the five vertebrates has been determined. The values obtained for birds and mammals are definitely higher, but there is a recession from fish to amphibian and increase from amphibian to reptile.

3. The amount of iron in 100 c.c. of corpuscles, considered as a measure of the amount of hæmoglobin, is much more in the fish than in any of the other animals, with that in the mammal mid-way between, and those in the amphibian and bird slightly more than that in the reptiles which is the least. The figures are not in agreement with similar ones quoted by Redfield and it is quite possible that the value obtained in the case of *Macrones gulio* is not representative of fishes.

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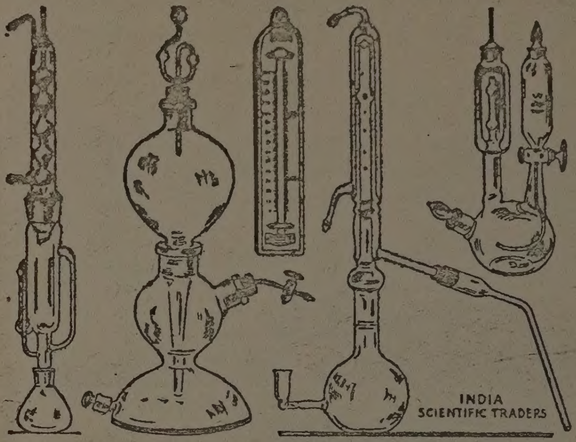

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